M18410

after three days' illness, COLONEL WILLIAM
WALFORD, late R.A., aged 61. Funeral at Freshwater, I.W., Friday. No flowers.

WATERS.—On the 8th June, at 69, Bedford-street, Liverpool, ALDERMAN THOMAS HOUGHTON WATERS, M.D., F.R.C.P., aged 86 years.

FUNERALS, CREMATIONS, EMBALMINGS, and Monumental Work, in Town, Country, or abroad.
PETER ROBINSON (Ltd.), 252 to 264, Regent-street, W. Telephone Gerrard 5835 (4 lines). Telegraphic address "Creational,

Times June 12. 1912

22101456429

Jubilee of Dr. A. T. H. Waters of
Liverpool – Brit. Med. Jnl. March 25, 1905.

THE ANATOMY

OF

THE HUMAN LUNG;

AN ESSAY,

TO WHICH WAS AWARDED THE
FOTHERGILLIAN GOLD MEDAL
OF
The Medical Society of London.

BY

A. T. HOUGHTON WATERS,

MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS OF LONDON,
LECTURER ON ANATOMY, PHYSIOLOGY, AND PATHOLOGY, IN THE LIVERPOOL ROYAL INFIRMARY SCHOOL OF MEDICINE,
PHYSICIAN TO THE LIVERPOOL DISPENSARIES.

LONDON:
JOHN CHURCHILL, NEW BURLINGTON STREET.
LIVERPOOL:
ADAM HOLDEN, CHURCH STREET.

MDCCCLX.

CANCELLED

95400

WELLCOME INSTITUTE
LIBRARY

Coll.	welMOmec
Call	
No.	WF600
	1860
	W32a

M18410

TO THE

PRESIDENT, VICE-PRESIDENTS, COUNCIL,

AND

FELLOWS OF THE MEDICAL SOCIETY OF LONDON,

THIS FOTHERGILLIAN ESSAY

IS RESPECTFULLY DEDICATED

BY

THE AUTHOR.

Digitized by the Internet Archive
in 2014

https://archive.org/details/b20400561

CONTENTS.

Page
PREFACE - - - - - - - - - - ix.

Part I.

HISTORICAL SKETCH.

Opinions of Hippocrates — Aristotle — Celsus — Galen — Theophilus Protospatharius — Aben Sina — Mundinus — Berenger — Vesalius — Vidus Vidius — Bauhin — Eustachius — Marchettis — Malpighi — Bartholin — Thruston — Diemerbroeck — Willis — Borel — Rivinus — Duverney — Helvetius Hamberger — Haller — Sœmmering — Reisseisen — Magendie — Home and Bauer — Bazin — Bérard — Berres — Lereboullet — Bourgery — Addison — Eichholz — Rainey — Moleschott — Rossignol — Adriani — Kölliker — Schultz — Williams — Mandl — Milne-Edwards - - - - - 1

Part II.

GENERAL CONSIDERATIONS - - - - - 37

CONSTITUENT PARTS OF THE LUNGS.

I. The Pleuræ.

Number, &c.— Reflections and Relations — Right Pleura — Left Pleura — Line of Reflection below — Shape — Connections — Fibrous Septum between the thorax and neck — Structure of Pleuræ — Vessels — Uses - - - - 41

II. The Trachea.

Page

Its Nature — Situation and Extent — Direction — Dimensions — Shape — Mobility — Relations: of Cervical portion; of Thoracic portion — Structure: 1. Fibrous Coat; 2. Cartilages; 3. Muscular Fibres; 4. Elastic Tissue; 5. Mucous Membrane; 6. Glands; 7. Blood-vessels; 8. Lymphatics; 9. Nerves - - - - - - - - - - 56

III. The Bronchi.

Number, &c. — Right Bronchus — Left Bronchus — Structure: Fibrous Tube; Cartilages; Muscular Fibres; Elastic Tissue; Mucous Membrane; Blood-vessels; Nerves 85

IV. The Substance of the Lungs.

Constituent parts — Root of Lung — Situation — Relations — The Lungs — Situation — Form, Divisions, Size, &c. — Surfaces and Borders — Colour — Texture and Consistence — Elasticity — Weight — Areolar Tissue - - - 90

V. The Bronchial Tubes.

General Arrangement, Mode of Division, &c. — Shape and Appearance — Alveoli — Structure: Fibrous Tube; Cartilages; Muscular Tissue; Elastic Fibres; Mucous Membrane; Glands - - - - - - - - - 107

VI. The Ultimate Pulmonary Tissue.

Appearances presented by the Ultimate Pulmonary Tissue under various modes of examination — Termination of the Ultimate Bronchial Tubes — names given to the Ultimate Air-canals by different authors — the propriety of these names considered — the term used by the Author — the Air-sacs: their arrangement — the Alveoli: their arrangement and number — the propriety of the term Alveolus considered — the arrangement of the air-sacs in groups or lobulettes: the shape of the lobulettes — best method of demonstrating their arrangement — Do the Air-sacs com-

Page

municate with each other? — Resemblance between the Air-sacs and the Pulmonary Sac of Batrachians — Structure of the Air-Sacs and Alveoli: Elastic Tissue; Basement Membrane; Epithelium — Dimensions of the Ultimate Bronchial Tubes, Air-sacs, and Alveoli — Difference in Size of the Air-sacs at different periods of life — no difference in different parts of the Lungs — Mode of preparing the Lungs for examination - - - - - - - - - 123

VII. The Blood-vessels.

They consist of two sets — the Pulmonary Arteries and Veins; the Bronchial Arteries and Veins. The Pulmonary Artery: its Course and Relations; Dimensions — Right Pulmonary Artery: Dimensions — Left Pulmonary Artery: Dimensions — the Pulmonary Veins: the Right Veins; the Left Veins — the Pulmonary Arteries within the Lungs — Arrangement of the Capillaries in the Air-sacs and Alveoli — Size of the Capillaries, and of the meshes of the Capillary Plexuses, of the Air-sacs — the Pulmonary Veins within the Lungs — the Bronchial Vessels — the Arteries: their number, &c. — Distribution of the Bronchial Arteries and Veins, and their mode of communication with the pulmonary system of vessels — Observations of Rossignol; of Adriani; of Dr. Heale; of Dr. Williams; of Kölliker; of the Author — Course and Distribution of the Bronchial Arteries — Communication between the Bronchial and Pulmonary Vessels — the Bronchial Veins — Observations of Reisseisen - - - - - - - - - - 172

VIII. The Lymphatics.

They consist of two sets — the Superficial Lymphatics: Course, &c. — the Deep Lymphatics: Course, &c. — the Lymphatic Glands - - - - - - - - 208

IX. The Nerves.

Their Source — they form Two Plexuses — Course and Distribution of the Branches of the Plexuses — Observations of M. Sappey - - - - - - - - 210

X. The Fœtal Lungs.

Page

The Pleura — the Trachea: Relations — the Bronchi — the Substance of the Lungs; Situation; Colour; Texture and Consistence; Weight, Absolute and Relative; Specific Gravity — the Air-tubes, Blood-vessels, and Ultimate Pulmonary Tissue - - - - - - - - - 215

XI. The Development of the Lungs.

Development of the Lungs in Birds and Mammals — Views of Von Baër, Valentin, Rathké, Müller, Reichart, Bischoff, Kölliker, Mandl — Investigations of the Author - 224

CONCLUSIONS - - - - - - - - 232

PREFACE.

FOR the following Essay the Medical Society of London awarded to the Author the Fothergillian Gold Medal of the past year.

In the composition of the work the Author has endeavoured to divest its pages of all matter foreign to the subject of the Essay, and to confine himself strictly to a description of the structures he has investigated.

The subject, for a treatise on which the Medal was offered, viz., "The Anatomy of the Human Lung," prevented the introduction of detailed observations on the lungs of the lower animals; an extensive series of investigations of these organs was, however, instituted, for the purpose of comparison.

The examination of the various structures of the LUNGS necessarily occupied a considerable portion of the Author's time, and from the period when he commenced his researches, when he first saw the advertisement of the Society, to the time when the

Essay was deposited at their rooms, scarcely a day elapsed — except during temporary absence from home — some portion of which was not devoted to the investigation of the subject or the preparation of the treatise. The portion which relates to the descriptive anatomy of the Lungs was the result of the Author's own dissections and observations of a considerable number of bodies; and in the progress of the entire work he has been careful to make no statement, on his own authority, until repeated examination convinced him of its truth; he feels, however, that some parts of the work are imperfect and incomplete, but, from various causes, he has been unable to resume his investigations.

In that part of the Essay which treats of the bronchial blood-vessels, the Author's views will be found to differ from those of previous investigators, with the exception of Reisseisen. The conclusions of the Author, as to the non-existence of bronchial veins *within* the lungs, were arrived at before he was aware of Reisseisen's views, and it is a source of great satisfaction to him to find that his opinions on this subject are in accordance, for the most part, with those of so distinguished an observer. It is remarkable that views of so weighty a character, with reference to a fact which may have important bearings on the pathology of the Lungs, should have been overlooked, or, at any rate, should have remained without confirmation, for a period of nearly sixty years.

Rich as is the English language in monographs on special subjects, it has been singularly deficient in treatises on the anatomy of the Lungs. Whether the Author has succeeded in presenting to the profession a trustworthy exposition of the structure of one of the most complex organs of the body,— an exposition which shall be alike serviceable to the student of Physiology and Pathology,— he must leave others to determine.

The Author desires to express his thanks to the following gentlemen, for valuable aid rendered him during the prosecution of his labours:—

To Mr. W. H. Manifold, for assisting him in the translation of passages in the works of some German authors he had to consult; to Mr. M'Caul, for helping him in the preparation and injection of the specimens used for examination; to the House Surgeons of the Royal Infirmary (especially Mr. Allen), and of the Workhouse Hospital, for facilities afforded in procuring specimens of the human lung; and to Mr. Desmond, Mr. Grimsdale, and other gentlemen, for several human embryos at various periods of growth.

Hope Street, Liverpool,
January, 1860.

THE HUMAN LUNG.

PART I.

HISTORICAL SKETCH.

CONTENTS.

Opinions of Hippocrates—Aristotle—Celsus—Galen—Theophilus Protospatharius — Aben Sina — Mundinus — Berenger — Vesalius — Vidus Vidius — Bauhin — Eustachius — Marchettis — Malpighi — Bartholin — Thruston — Diemerbroeck — Willis — Borel — Rivinus — Duverney — Helvetius — Hamberger — Haller — Soemmering — Reisseissen — Magendie — Home and Bauer — Bazin — Bérard — Berres — Lereboullet—Bourgery—Addison—Eichholz—Rainey—Moleschott—Rossignol — Adriani — Kölliker — Schultz — Williams — Mandl — Milne-Edwards.

From the very earliest period of the cultivation of anatomical science, the anatomy of the Human Lung has occupied the attention of observers. It could scarcely fail to happen that the importance of the organ should be early recognised, and that wherever men were engaged in investigating the structure of the body, this particular viscus should receive careful examination; but we nevertheless find that up to the middle of the seventeenth century, when the powers of the microscope were first brought to bear on the examination of its tissues, the most crude and imperfect notions prevailed with respect to its intimate nature. In writing an Essay on the "Anatomy of the Human Lung," I conceive it to be most important to give a historical sketch of the labours of others in this department of science, as well on account of the interest which must necessarily be attached to their investigations, as that the various views which have been promulgated by different authors may be fairly brought forward, and, if necessary, discussed; and in this sketch I shall include, as far as I have been able to gather them, the opinions enunciated by observers, from the time of Hippocrates downwards, more especially with reference to *the ultimate arrangement of that portion of the pulmonary substance which constitutes the essential part of the respiratory apparatus—that part in which the function of the organ is performed.* The quotations which will be found, except where otherwise stated, have been verified by personal examination of the original works of the authors to whom they are ascribed, and although I have not been able to examine all the literature bearing on the subject, yet I believe I have omitted to notice the remarks of no original observers.

Hippocrates, 460 B. C., is the first author whom we find writing of the structure of the lungs, and the description he gives of them is very meagre and incomplete. He describes them as of a spongy and cavernous character, and interspersed with many small vessels.*

---

* "Pulmo autem juxta cor sic extitit. Quod in humido glutinosissimum erat, cor calefaciens, celeriter exsiccavit, veluti

Aristotle, 384 B. C., mentions with reference to the lungs of man, that they differ from those of the lower animals, in that the former are not divided into so many lobes as the latter. He describes the lungs as spongy, and receiving into the several canals blood from the great vein.[*]

Celsus, 29 B. C., describes the lung as joined behind to the spine, and divided into two lobes; as spongy in its character, and thereby capable of containing a large quantity of air.[†]

Galen, A. D. 131, wrote but little more accurately of the structure of the lungs. He describes them as covered by the membranes which divide them into two portions.[‡] "Their substance," he says, "is composed, like that of the liver, of many vessels, the spaces between which are filled with a soft, flock-like flesh."[§] He mentions that there are two lobes on each side of the chest, one occupying the upper, the other the lower part, near the diaphragm, and that the fifth lobe is small, making a triangle on the right side for the support of the vena cava.[||]

---

spumam et fistulosum reddidit, multisque venulis respersit."—*Hippocrates de Carnibus*, Op. om., Kühn's translation, p. 431.

[*] *Aristoteles*, *Hist. Animal.*, lib. i. cap. 16, 17.

[†] "Is spongiosus ideoque spiritus capax, et a tergo spinæ ipsi junctus, in duas fibras, ungulæ bubulæ modo dividitur." — *Celsus*, lib. iv. cap. i.

[‡] *Galenus*, *de usu partium Corp. hum.*, lib. vi. cap. 3.

[§] "Hoc itaque viscus quemadmodum hepar vasis quamplurimis veluti est contextum, quorum intervalla carne molli instar tomenti cujusdam opplentur."—*Ibid.*, lib. vii. cap. 2.

[||] *Ibid.*, lib. vii. cap. 10.

Theophilus Protospatharius, A. D. 800, and *Aben Sina*, are quoted by Moleschott as having written on the structure of the lung, which they compared to that of the liver. They seem not to have advanced beyond the description given by Galen.

From the period of Galen to the revival of the study of anatomy in the fourteenth century, I have been unable to discover the names of any authors, who contributed anything to the knowledge of the anatomy of the human lung; and the only two I can find quoted as having written on it at all, are those mentioned above.

Mundinus, who flourished in the fourteenth century (A. D. 1315), describes the lungs as consisting of two lobes on the left side and three on the right. "They are composed," he says, "of soft flesh and membranes."[*]

Berenger (Carpi), A. D. 1535, describes the lung substance as a thin, light, soft flesh, of reddish white, and having a composition, spongy and like a honeycomb.[†]

Vesalius, 1543, describes the lungs as consisting each of two lobes, but sometimes of three, and at other times undivided. He also refers to a fifth lobe, evidently meaning the third lobe of the right lung. "The substance of the lung," he says, "is a soft, spongy, thin, light, airy flesh, as if formed of frothy blood, or bloody froth, and abounding in many branches of vessels. ' *

---

[*] "Ipse (pulmo) compositus est, ex triplici usæ ex carne molli et panniculis."—*Mundinus, Anatomia—De Pulmon.*, p. 39.

[†] "Pulmonis substantia, mixta è ex carne rara, levi, leni, et rubea ad albedi. . . . . Hoc compositio est favo mellis et est spongie similis, ideo e sanguinis et aëris capax."—*Berenger (Carpi), Anatomia*, 1535.

Vidus Vidius, 1561—

Bauhin, 1588. Both these authors wrote on the structure of the lungs. In their remarks they seem to have borrowed from *Vesalius*, with whose observations they coincide. They describe each lung, however, as consisting of two lobes.†

Eustachius, A. D. 1563, has given an apparently original sketch of the lungs; the right is divided into three lobes, the left into two.‡

Marchettis gives an accurate description of the lungs, refers to a difference in colour in the upper and lower parts of the organ, and describes its substance as thin and spongy.§

We now arrive at an epoch of the greatest possible interest with reference to the subject we are considering. It will be seen, from the quotations I have made, that, up to the period we have reached, a very imperfect notion prevailed of the intimate structure of the human lung. Unable to follow the bronchial tubes to their termination by the unaided eye, our ancestors believed that the tissue, or parenchyma of the lung, was of a spumous or spongy character, and that in it the air became mingled with the blood. The discovery of the circulation created a new era in anatomical science. *Malpighi*, profiting by the improved knowledge of his day, by means of mercurial injections into the blood-vessels of the lungs, and by inflation of their tissue, proved that there was no communication between the vessels and the air tubes, and demonstrated the existence of a system of vesicles, in connection with the ultimate bronchial ramifications. In 1661 he published two letters, addressed to Borel, in which his observations on the lungs will be found. By diligent research he recognised that the whole mass of the lungs, held together by vessels running through it, was an aggregation of very fine and thin membranes, which, by their extension and tortuous course, formed an almost infinite number of *orbicular and sinuous vesicles*, in the same manner as we see wax spread out to form the parietes of the cells of the honeycomb. These vesicles, he said, had a communication with the trachea, and with one another.*

---

* "Utræque enim pulmonis partes in duos distinguuntur lobos. . . . . Neque etiam perpetuò in duos solum lobos pulmonis partes secantur, verum aliquando in tres, interdum in nullos. . . . .

"Quintum hunc pulmonis lobum eos non latêre qui recte sectionem administrant.

"Pulmonis substantia, caro est mollis, fungosa, rara, levis, aërea, ac velut ex spumoso sanguinie spumave sanguinea, concreta, multisque vasorum germinibus scatens."—*Vesalius, de Corp. Humani Fab.*, lib. vi. cap. 7.

† *Vidus Vidius, De Anat.*, p. 289. *Bauhin, Theat. Anat.*, edit. 1621. *De Pulmonibus*, p. 240.

‡ *Eustachius, Tab. Anat.*, tab. 15.

§ "Substantia cinericiam, in superiori parte, in inferiori rubicundam; rara et spongiosa in adultis."—*Marchettis, Anatomia*, cap. x. (1656).

When examined with magnifying power, these vesicles appeared to him to be formed by the attenuated continuation of the internal membrane of the trachea, which was dilated at its extremity and its sides into cup-like sinuses, and beyond these terminated in unequal spaces and vesicles, so as to offer the appearance of a sponge.*

---

* "Diligenti enim indagine adinveni totam pulmonum molem, quæ vasis excurrentibus appenditur esse aggregatum quid ex levissimis, et tenuissimis membranis, quæ extensæ, et sinuatæ penè infinitas vesiculas orbiculares, et sinuosas efformant, veluti

In his first letter he speaks of a network surrounding the vesicles, which he thought was for the purpose of connecting them together; but he doubted whether it was a vascular plexus or a nervous (fibrous) tissue. In his second letter, however, having made observations on the lungs of living frogs, he recognised the plexus as consisting of blood-vessels.

He describes the division of the lungs into lobules, and seems to have thought that the interlobular tissue consisted of true pulmonary vesicles, and that the air was received into and expelled from it, as with the vesicles, and that the membranes of the tissue had a communication with each other.† He

in apum favis alveolis ab extensa cera in parietes conspicimus; hæ talem habent situm, et connexionem, ut ex trachea in ipsas mox ex una in alteram patens sit aditus, et tandem desinant in continentem membranam."—*Malpighi*, *De Pulmonibus*, Ep. i.

* "Auctâ magnitudine . . . . istæ vesiculæ videntur efformari ex desinentia tracheæ, quæ extremitate, et lateribus in ampullosos sinus facessens, ab his in spatia, et vesiculas inæquales terminatur. Unde fortasse tunica illa interna tracheæ in sinus, et vesiculas terminata consimilem inchoatæ vulgò spongiæ vesicularum molem efficit. . . . ."—*Ibid.*, Ep. i.

† "Pulmonum enim moles lobulis penè infinitis propria membrana circumseptis."—*Ibid.*, Ep. i.

"Hisce membranis recipitur, et ejicitur aër, veluti in amplioribus sinibus, qui mutuam habent communionem, ut aër ex uno in alium comprimi possit, ita ut interstitia sint eædem membraneæ vesiculæ pulmonum diaphanæ tamen et tenuissimæ."—*Ibid.*, Ep. i.

subsequently speaks of having found cysts (hydatids) in these interstices, and also a black substance, and from this he is led to infer that the office of these spaces is to serve as emunctories or diverticula to the smallest lobules.

Bartholin, in 1663, wrote an essay on the lungs, which I regret I have not been able to meet with. In it he examines the opinions expressed by different authors from the time of Hippocrates, and adopts that of Malpighi. In speaking of the communication of the vesicles with each other, he says, "Vesiculæ omnes inter se patent, et inter singulas perpetuum liquorum est aërisque consensus."[*]

Thruston, in 1670, wrote a short account of the structure and function of the lungs, but there is nothing new in his observations; he quotes Malpighi.[†]

Diemerbroeck, 1675, in his anatomical works, treats of the lungs to a considerable extent; with reference to their intimate structure he quotes Malpighi.[‡]

Willis, a cotemporary of Malpighi, but writing subsequently to him, studied the anatomy of the lung by means of a mode of preparation not previously used, viz., the injection of mercury into the bronchial tubes. His observations led him to conclusions totally opposed to the views of the Italian anatomist.

---

[*] *Bartholinus, De Pulmonum substantia et motu diatriba*, sec. i. p. 335, *de l'edition ajouté à l'ouvrage de Malpighi*, Opera omnia. Lugd. Batav. 1687. Quoted by *Rossignol: Recherches sur la structure intime du Poumon de l'homme.*

[†] *Thruston, M., De Respirationis usu primario diatriba.* Londini, 1670.

[‡] *Diemerbroeck, De Pulmone et Respiratione*, Op. om., 1675.

According to Willis, each bronchial tube sends off a number of little branches, from which are given off innumerable lesser sprigs or branches. These branches, although they seem to touch each other, and to cleave together, yet are not connected with one another, but bounded by their own walls.

The bronchial tubes lead into the ultimate cavities, viz., into the numerous vesicles discovered by Malpighi, which are, in fact, continued parts of the trachea. All the bronchial tubes give off lesser branches, which are here and there, as it were, constricted by certain ligaments, and the spaces between these, being filled with air, partly form the small vesicular cells. These vesicular passages have, as it were, little bladders growing thick upon them, and the heap of cells therefore bears a resemblance to a bunch of grapes.*

---

* "Unusquisque enim ramus bronchialis plures hic illic ramulos, sive surculos à se mittit qui . . . . in minores indo propagines fere innumeras finduntur . . . . adeoque tota pulmonum compages è pluribus prædictorum vasorum ramificationibus complicatis constat. Quorum comæ et latera extrema, licet se mutuo tangere et cohærere videantur, tamen alia ab aliis disjuncta, et quæque intra proprios fines limitata existunt."—*Willis, de Respirationis Organis et Usu.* Om. op., Lugd., 1676.

"Fistulæ bronchiales in cavitates ulteriores, scilicet in vesiculas numerosas, à Malpighi inventas, ducunt; quæ quidem asperæ arteriæ continuæ quædem partes sunt, verùm a prioribus distinctæ eo quod cartilagines iis prorsus desunt. . . . . Enimvero rami quique bronchiales surculos minores quaquaversus à se mittunt; quorum ductus . . . . ad certa tamen intervalla quibusdam quasi ligamentis coarctantur; atque horum intercapedines, aëre inspirato impletæ cellulas istas vesiculares ex parte efficiunt— . . . . Porro ductus isti vesiculares ex utroque latere sinus breviores, tanquam vesiculas singulares densissimè accrescentes

In one of his plates, in which he represents the arrangement of the structures above described, the sketch resembles a number of small rounded leaves, connected by their petiole to a stalk, which itself terminates in a similar leaf. The ultimate ramifications, therefore, of the bronchial tubes, or air-vesicles, according to Willis, have no communication the one with the other; he describes their walls as furnished with muscular fibres, as well as those of the trachea and bronchi. The existence of these fibres on the walls of the vesicles he considered it too easy to prove, by the aid of the microscope, to leave the least doubt. He also believed that the vesicles contracted during expiration.*

Borel, 1681, described the air-cells as *Malpighian vesicles.* He denied the existence of muscular fibres in the walls of the cells, or that the lungs had any movement of themselves.†

Rivinus, in a dissertation in 1686, described the lungs as perforated like a sponge, and capable of absorbing fluid effused into the chest.‡

Duverney (l'ainé), is quoted by some authors as having written on the structure of the lungs: the

---

habent, proindeque cellularum omnium aggeries uvarum racemo haud multum absimilis videtur." —*Ibid.*

* Cellulæ istæ vesiculares, ut nixus pro expiratione contractivos edant, etiam fibras, uti per microscopium planè conspicere est, musculares obtinent. — *Ibid.*

† *Borel, De motu animantium, pars secunda. Hagæ Com.*, 1743.

‡ Parum proinde abest, quin statuamus pulmonis in superficie perforatas instar spongiæ absorbere saniem illam, eandemque postmodum ad arteriam asperam ablegare ad exspuendum.—*Rivinus, de Empyemate Thoracis*, 1686.

only article I have been able to find from his pen bearing on the subject is one presented to the Royal Academy of Sciences of Paris, on the circulation of the blood in fishes, and on their respiration: in this paper, after describing the structure of the gills in the fish, and the mechanism of their respiration, he alludes to the vesicular nature of the lungs of animals, but offers no new remarks on them.*

In Duverney's anatomical works, published after his death, in 1761, that portion which treats of the human lung is a reprint of an article presented by Helvetius to the Academy of Sciences, in 1718, and to which I shall have to allude.

Helvetius, in the early part of the eighteenth century, made some original observations on the structure of the lungs. He denied the existence of vesicles, or that the cellular or spongy tissue of the lung was formed by an expansion of the bronchial tubes, or that its cells or cavities consisted of a prolongation of the same membranes. "The small elevations," he says, "which appear externally when a moist or humid lung is inflated, are produced by the effort of the air against the external membrane of the lung."† He considers the lobules as consisting of spongy tissue, separated and enclosed by a thin membrane;[*] this membrane he believes to be derived from the external layer of the pleura, which, having reached the body of the lung, plunges into its substance, and at last is lost in the lobules which it seems to form.[†] All the cells of a lobule dilate together, either from communicating with one another, or else by communicating with a branch of the trachea by an infinity of small branches.[‡] The distinctive character of the opinion of Helvetius with respect to the ultimate pulmonary tissue is this— that it consists of cellular tissue derived from the membrane of the pleura, which enters the lung, as mentioned above, and in its arrangement resembles the structure of the sheep's spleen. "I look upon this mass of cells," he says, "as a spongy or cellular tissue, in which the air brought by the ramifications of the bronchial tubes, is diffused in the

---

* *Duverney, Memoires de l'Academie Royale des Sciences*, 1701. Article — *Sur la circulation du sang des Poissons qui ont des Ouies, et sur leur respiration.*

† "Ces observations me persuadent. 1°. Qu il n'y a point de vésicules. 2°. Que les cellules ou cavités qui forment le tissu spongieux ne sont pas un epanouissement des bronches, et qu'elles ne sont pas formées par les mêmes membranes. 3°. Que les petites élévations qui paraissent exterieurement lorsque l'on souffle

---

un poumon frais ou humide, ne sont produites que par l'effort de l'air contre la membrane externe du poumon."—*Helvetius, Memoires de l'Academie Royale des Sciences*, 1718, p. 28.

[*] "A l'égard des lobules se sont des portions de ce tissu spongieux separés et renfermés par une membrane assez mince."—*Ibid., p.* 28.

[†] "Elle (la membrane externe de la plèvre) se replie avec la membrane interne de la plèvre, . . . elle s'etend . . . jusqu'au corps du poumon. Pour lors elle s'enfonce dans l' interieur du poumon, et elle se perd enfin dans les lobules qu'elle semble former."—*Ibid.*, p. 21.

[‡] "Toutes les cellules de ce corps spongieux renfermé dans un lobule se gonflent toujours en même temps, ou parceque les cellules d'un même lobule ont communication les unes avec les autres, ou parceque l'air soufflé par une ramification de la trachée artère dans ce lobule, se distribue en même temps dans toutes les cellules par une infinité d'autres petites ramifications qui sortent de cette première."—*Ibid.*, p. 29.

same manner as the blood is diffused in the cells of the sheep's spleen, or as it is poured into the cavernous body."[*]

The mode of termination of the bronchial tubes, and their mode of communication with the pulmonary cells, is not very clearly made out by Helvetius; he describes the bronchial extremities as appearing to plunge into the spongy tissue.[†] He recognised that the cells of one lobule did not communicate with those of another, a fact not ascertained by Malpighi.

Hamberger, E. G., in 1748, wrote a dissertation, in which he describes the structure of the lungs, but his remarks present nothing new; he describes the lobules as composed of many cells, communicating with each other, and surrounded by a common membrane. He refers to Malpighi and Helvetius.[‡]

Haller admits the cellular structure of the lungs as described by Helvetius. He does not believe that each bronchial ramification terminates in a single cup-like expansion, and says that the lobules are separated from each other, and do not communicate, but that the small cavities of each lobule communicate freely with each other.* He denies the existence of muscular fibres in the walls of the cells of the lung in man, for he says their existence in the lung of the frog is not proved by sufficiently strong experiments, and certainly the lung of quadrupeds is not endowed with an irritable nature.† He mentions that the theory of Helvetius did not prevail against the generally received opinion that the lung tissue consisted of a system of *air vesicles.*‡

---

[*] "Je regarde cet amas de cellules comme un tissu spongieux ou celluleux, ou l'air porté par les ramifications des bronches, se répand comme le sang se répand dans les cellules de la rate du mouton ou de la même manière qu'il est versé dans le corps caverneux." — *Ibid.*, p. 32.

[†] "On les voit (les ramifications des bronches) quelquefois se fourcher en deux ou trois branches vers leurs extremités, de la manière que nous le voyons souvent arriver à la pointe des cheveux. Au reste ces extremités paraissent s'enfoncer dans le tissu celluleux ou spongieux." — *Ibid.*, p. 27.

[‡] *Hamberger, Dissertatio de Respirationis Mechanismo atque usu genuino*, 1748.

Soemmering. The opinion expressed by Haller is also that expressed by this celebrated German anatomist. He described the substance of the lungs as composed of small cells, vesicles, or sacculi, full of air. These cells are polygonal and irregular; when inflated, they have a diameter of about one-eighth or one-tenth of a line. The cells of adjoining lobules do not communicate together, but those of each lobule do so. The air-cells of the lungs are formed of a delicate membrane, impervious to air, which is scarcely the thousandth part of an inch thick, and for the most part consists of the network of blood-vessels.* In these polygonal and irregular cells above described the bronchial tubes terminate.†

---

* "Id vero utique cum omnibus meis, calidorum et frigidorum animalium, incisionibus consentit, non in aliquam singularem ampullam quemque ramum bronchi terminari, sed cellulosum opus in humano, perinde ut in ranino pulmone esse, cujus cavernulæ imperfectæ inter se libere communicent, donec aëris iter lobuli cujusque vagina moretur, prohibeatque, ne de lobulo in vicinum lobulum transeat."—*Haller, Element. Physiol.*, 1761, vol. iii., p. 179.

† "Ergo ex hâc descriptione primum oportet musculosam pulmonis fabricam resecare, quæ omnino ab homine penitus abest, neque satis firmis experimentis etiam in rana nititur. Pulmo certe quadrupedum irritabili natura destituitur."—*Ibid.*, p. 176.

‡ "Non prevaluit ill. viri sententia contra receptam opinionem, soletque mentibus hominum diversum in pulmone aëreum et vesiculosum systema placere," etc. —*Ibid.*, p. 178.

Reisseisen. At the beginning of the present century, an elaborate essay appeared on the structure of the human lung, written by Reisseisen, which received the first prize of the Royal Academy of Berlin, a second prize being given for an essay written by Soemmering. Reisseisen revived the apparently then almost forgotten theory of Willis, with respect to the termination of the bronchial tubes; and, having fortified his opinions with numerous experiments which seemed conclusive, his views received, for a time, almost universal assent. The methods of preparation employed by Reisseisen were, first, injection of mercury into the bronchial tubes, and, secondly, the partial exhaustion of the air from the lungs.

---

* "Pulmonum substantia parvis cellulis, vesiculis, vel sacculis aëre plenis conflatur. . . . . Cellulæ hæ teretes, multangulæ atque irregulares apparent; inflatæ octavam circiter vel decimam lineæ partem diametro absolvunt. . . . . Neque vero lobulorum vicinorum cellulæ inter semet ipsæ communicant, sed non nisi cellulæ ad suum quemque acervulum aut lobulum pertinentes, Cellulæ hæ pulmonum quæ vocantur aëreæ, e membrana aëri impervia, vel e tenella, quæ vix millesimam pollicis partem crassa est, et pleraque e solo vasorum sanguiferorum reticulo constat, membrana contextæ sunt." — *Soemmering, De Corporis Humani*, vol. vi., pp. 14, 15.

† "Bronchus dexter et sinister, dum certo quodam ordine magis magisque imminuuntur atque extenuantur, per totos pulmones arborum instar in ramos discedunt, usque dum tenerrimis tandem staminibus in cellulis aëreis supra descriptis cœcis desinant." — *Ibid.*, p. 35.

He directs that mercury should be poured into the bronchial tubes of a thin piece of lung, and that it should be gently driven to the end of the tubes by pressure with the handle of a scalpel; by examination with a simple lens, it is then easily seen that the mercury runs into branches, which become gradually finer and shorter, more numerous and compact, as they are distant from the upper branches, until at length it remains at the surface of the lung in the shape of *half-globular eminences* beneath the pleura.*

In speaking of the divisions of the bronchial tubes, he says that they become so numerous towards the end, that from every part of their circumferenee new branches proceed, which, when filled with mercury, resemble nodules, and that the terminal branches become so short that they appear only like half globules, or the grape-like clusters of a cauliflower.

From the examination of the lung partly exhausted of air, but in which some of the air-tubes remained distended, he came to the same conclusions as from his previous experiment. His observations are summed up as follows: "The air tube is divided into branches, which go on diminishing in diameter, and at the same time increasing proportionately in number, until at length the last branch terminates in a rounded extremity. It does not pass into cellular tissue, nor become changed into such, but preserves its structure to the extreme branches, by the cœcal terminations of which it forms the so-called air-cells or vesicles."*

---

* "In bronchium excisi pulmonum lobuli, qui in hominibus ex margine acuto, ubi lobuli sic excurrunt ut extremi simplices evadant, ... hydrargyrum infundas, illoque in plano posito scalpelli capulo adeo propellas, ut extremo in margine undatim promineat. Oculo deinde simplici vitro lenticulari armato, facile animadvertes, hydrargyri columnas in ramulos excurrere sensim gracilescentes eoque breviores, quo longius a superioribus, partitionibus absunt, numero vero et densitate usque augescentes donec illud ad marginem in formam globulorum dimidiatorum abeat sub pleura eminentium."—*Reisseisen de Fab. Pulmonum*, 1823, p. 7.

Notwithstanding the success which attended the work of Reisseisen, it failed to convince all anatomists, and in this country, as well as in France, opposite views soon began to prevail.

Magendie, in 1821, published some observations made by him on lungs, which he had inflated and dried. He does not admit that the pulmonary vesicles are the termination of the air-canals, and gives them the name of *cells (cellules)*, as more appropriate than that of *vesicles (vésicules)*. "We do not see," he says, "the air-canals reach as far as the cells; they evidently stop when they have arrived at the lobule for which they are destined. The mucous membrane also seems to cease at this point; at least, it is quite impossible to follow it along the vascular divisions which chiefly form the lobule. All the cells of a lobule communicate with one another, but not with those of the adjoining lobules."†

---

* "Fistula igitur spiritalis in ramos dividitur certa constantissimaque ratione et diametro decrescentes et numero augescentes, usque dum cœcis terminetur finibus iisdemque rotunde clausis. Nec ideo in telam cellulosam abit hujusve naturam recipit, sed propriam ipsius fabricam ad extremos usquè fines servat, quibus ut dixi clausis, cellulas refert, sive vesiculás aëriferas."—*Ibid.*, p. 11.

† "On ne voit point les canaux aérifères arriver jusqu'à ces cellules; ils s'arrêtent evidemment au moment où ils sont par-

Some years after, he makes the following remarks: "As to the vesicles described by some anatomists, they do not exist. These pretended dilatations, suspended to the bronchial tree, like grapes on a branch, are only to be found in books, and not in nature. It is now quite evident that there is only a spongy tissue, formed by the arrangement of the vessels, which leave between them small spaces in which the air can penetrate freely."*

He endeavours to disprove the value of Reisseisen's experiments, and objects to the method of injecting the air-tubes with mercury, maintaining that the metal itself produces the *culs-de-sac* which the Prussian author describes. "Examine," he says, "under the microscope, a slice of lung, dried after a previous inflation; you will find nothing which approaches to a termination in *cul-de-sac*."†

---

venus au lobule pour lequel ils sont destinés ; la membrane muqueuse parait aussi s'arrêter à ce point ; du moins il est tout à fait impossible de la suivre sur les divisions vasculaires qui forment principalement le lobule. Toutes les cellules d'un lobule communiquent entre elles, mais non avec les cellules des lobules voisins."—*Magendie, Journal de Physiologie Experimentale*, 1821, tom. i. p. 78.

* "Quant aux vésicules qui ont été descrites par quelques anatomistes elles n'existent point. Ces pretendues ampoules suspendues à l'arbre bronchique, comme les grains de raisin à la grappe, ne se trouvent que dans les livres, et nullement dans la nature. . . . . Il est de toute evidence maintenant, qu'il n'y a qu'un tissu spongieux formé par l'arrangement des vaisseux, qui laissent entre eux de petits espaces où l'air peut librement penetrer."—*Leçons sur les Phenomènes Physiques de la Vie*, Paris, 1837, vol. ii. p. 87.

† "Examinez au microscope une tranche de poumon desséché apres une insufflation préalable, vous ne trouverez rien qui se rapproche d'une terminaison en cul-de-sac."—*Ibid.*, vol. ii., p. 93.

Magendie was the first who observed, that a difference exists in the size of the pulmonary cells at different periods of life. He says they are smallest in infancy, and increase in size as age advances.*

Home and *Bauer*, in the "Philosophical Transactions" of 1827, published some remarks on the lungs. "The cells of the human lungs," they say, "are not dilatations of the bronchial tubes, but are regular cells, in which the tubes terminate."†

Bazin. — In some observations presented to the Academy of Sciences of Paris, this author supports the opinions of Reisseisen, having used the same method of preparing the lungs for examination as the latter did, viz., the injection of mercury into the bronchial tubes.

"The bronchial tubes," he says, "having divided and subdivided, terminate by giving off very short branches, which end in culs-de-sac. It is the extremities of these ramifications, and the swellings they present when they are distended, that most anatomists have taken for cells or vesicles."‡ He assured himself, by numerous preparations both of the lungs of man and other mammifers, that the membrane lining the trachea, the bronchial tubes and their branches, and lastly, the terminations in culs-de-sac, have no communication with each other, but through the medium of the trunk or bronchial ramification from which they arise, and that there exists no anastomosis between the bronchial cœcal extremities, nor between one division of the air-tubes and another.*

---

* "J'ai été frappé de la variation de grandeur qu'elles (les cellules) eprouvent par le progrès de l'âge: leur nombre est en raison inverse des années, et par consequent chacune est d'autant plus spacieuse que le sujet est plus vieux."—*Journal de Physiol. cit.*

† *Philosophical Transactions*, 1827.

‡ Les bronches après s'être divisées, sub-divisées . . . . finissent par donner des ramuscules tres courts qui se terminent en cul-de-sac. Ce sont les extremités de ces ramifications, et les renflements qu'elles presentent quand elles sont distendues, que la plupart des anatomistes ont pris pour des cellules ou des vésicules. — *Comptes-Rendus de l'Academie Royale des Sciences — Memoire du Dr. Bazin. Sur la Structure intime du Poumon*, vol. ii., p. 515.

Bérard, in 1836, wrote a thesis on the lungs, and thus speaks of the arrangement of the ultimate bronchial ramifications: "If we further inspect each lobule, we see the bronchial tube, which has penetrated into its interior, giving rise to branches which diverge from the centre of the lobule to its periphery; they undergo many secondary divisions, and terminate in culs-de-sac, either in the substance or at the superficies of the lobule. Constrictions placed at a short distance from each other, give a moniliform appearance to each terminal bronchial division; similar depressions are equally observed on the rounded cul-de-sac of the last subdivisions; so that the mass of terminal bronchial ramifications resembles very nearly branches of coral. In giving, with Malpighi, the name of vesicle to each cul-de-sac which terminates a bronchial twig, I do not mean to say that there is an ampullated swelling; this swelling comes perhaps with the progress of age, but at first the extremity of the bronchial tube is simply rounded."*

---

* "Je me suis assuré par de nombreuses preparations faites sur le poumon de l'homme, et sur celui d'un grand nombre de mammifères, que la membrane aérifère qui tapisse la trachée artère, les bronches, les rameaux, les ramuscules, et enfin les terminaisons en cul-de-sac ou cœcum, n'ont entre elles de communication que par le tronc ou la ramification bronchique, qui leur donne naissance, et qu'ainsi il n'existe aucune anastomose soit entre les cœcums bronchiques, soit entre une division quelconque des conduits aériens et une autre."—*Ibid.*, vol. ix. p. 153.

Berres has made some remarks of importance in his work on microscopical anatomy. After mentioning that the smallest bronchial ramifications, going to the periphery of the lungs, are furnished with air-vesicles, he proceeds to describe the latter; he says they are not always spherical, and that the cavity of each vesicle is enlarged by from twelve to thirty-two sinuses, whence it assumes the external shape of a blackberry or strawberry. He says that the distinction between pulmonary vesicles and cells is not a fictitious or imaginary one, but supported by anatomical conditions. The pulmonary vesicle is, as it were, the ampulated extremity of the air-tube, the sinuosities of which may be properly termed cells.*

---

* "Si l'on pousse plus loin l'inspection de chaque lobule, on voit la bronche qui a pénetré à son interieur, donner naissance à des ramifications, qui divergent toutes du centre du lobule à la péripherie; elles éprouvent des divisions secondaires multipliées, et se terminent en culs-de-sac, soit dans l'épaisseur soit à la superficie du lobule. Des etranglemens placés à peu de distance les uns des autres, donnent un aspect moniliform à chaque division bronchique terminale; des depressions analogues s'observent egalement sur le cul-de-sac arrondi des dernières subdivisions, en sorte que l'ensemble des ramifications terminales des bronches figure assez bien des rameaux de corail. En donnant avec Malpighi le nom de vésicule à chaque cul-de-sac qui termine un tuyau bronchique, je ne veux pas dire qu'il y'ait un renflement ampoule; ce renflement survient peut-être par le progrès de l'âge; mais dans le principe l'extremité de la bronche et simplement arrondie."—*Bérard, Texture et Development des Poumons,* 1836; quoted from *Adriani de Subtiliori Pulmonum Structura.*

Lereboullet, 1838, adopts the opinion of Reisseisen, which he defends at very considerable length. He describes the bronchial tubes as dividing into a large number of branches, and terminating in culs-de-sac, which do not experience any sensible dilatation.† The terminal cells, or rather *capsules*, of the bronchial tubes are extremely numerous. They are distinct from one another, and do not communicate, except through the bronchial canal, of which they are the termination.‡

Lereboullet attacks the mode of preparation of the lungs, previous to examination, used by Malpighi, Helvetius, Magendie, and others, viz., inflation and subsequent desiccation, and endeavours to prove that the method adopted by Reisseisen is the only one to be relied on.

---

* "Considerando vesiculam pulmonalem, . . . hanc non prorsus sphaericam esse fateri debemus. Primo enim obtutu observamus, cavum ejusmodi vesiculæ duodecim usque triginta duobus sinubus amplificari, unde formam externam fructus rubi vel fragi mentitur.

"Ex dictis elucit discrimen vesicularem et cellularum pulmonalium non fictitium vel imaginarium esse, sed rationibus anatomicis perpetuis inniti. Vesicula enim pulmonalis tubuli aerophori quasi ampullam sistit, cujus sinuositates cellularum nomine notare aptum erit."—*Berres*, *Anatomia Microscopica Corporis Humani*, 1837; quoted from *Adriani*, Op. cit.

† "Lesquels (les bronches) se subdivisent eux-mêmes en une multitude de branches et de rameaux, et se terminent par des culs-de-sac, sans que ceux-ci éprouvent de dilatation sensible."—*Lereboullet*, *Anatomie Comparée de l'Appareil Respiratoire*, p. 25. Strasbourg, 1838.

‡ "Les cellules ou plutôt les capsules terminales des bronches sont extrêmement nombreuses. Elles sont distinctes les unes des autres, et ne communiquent entre elles qu'au moyen des canaux bronchiques dont elles sont la terminaison."—*Ibid.*, p. 25.

Bourgery, in a paper read before the Royal Academy of Sciences of Paris in 1836, and subsequently in his work on Anatomy, attacked the theory of Reisseisen and Willis, and developed an entirely novel one of his own. He made use of the two modes of preparation adopted by his predecessors, but relied most on inflation and desiccation. His observations led him to believe that no vesicles exist in the lung; that the ultimate pulmonary tissue consists of a series of canals, which anastomose directly with each other. If we examine a slice of lung, we shall find it composed, according to M. Bourgery, entirely of canals and their walls. These canals are riddled by other canals much smaller, and, however divided, appear equally varied in their direction; the greater number are perpendicular to the surface, or oblique, and here and there some are parallel or horizontal, presenting the appearance, when divided, of a gutter. All the canals are very tortuous, and open into one another at their extremities, or in their circumference, by a large number of orifices.

No canal gives the idea of a cul-de-sac or cœcum. There are none which are not open at least by both ends, but always in making a bend. Amongst the large ones nearly all receive besides, in their course, one or several openings of similar canals; lastly, a number of small canals open into them.

These canals give the appearance of a space very much divided by thousands of tortuous branches;

which space is continuous, and in which there is nothing terminal except the orifice of entrance, at which the orifice of exit is also found. It presents the image of a true *labyrinth.* This has induced me to call the canals *canaux labyrinthiques aérifères.**

Addison.—Nearly at the same time that Bourgery made his observations public, Addison instituted an investigation of the lungs. He remarks: "Having examined the structure (of the lungs), recent and dry, in every possible way I could devise, I nevertheless always failed to discover any *tubes* ending in *culs-de-sac;* on the contrary, I always saw air-cells communicating with each other in every section I made. I therefore repeated Reisscisen's experiments, and instituted others, from which I derived ample evidence that the *bronchial tubes*, after dividing into a multitude of minute branches, which take their course in the cellular interstices of the lobules, terminate in their interior in *branched air-passages* and freely communicating *air-cells.*"

---

* "Ici ce n'est donc point une petite sphère ou *vésicule* que l'on a sous les yeux, mais une cavité cylindrique ou un *canal.* Que si l'on promène le champ d'observation de la lentille sur la surface de l'objet, on voit qu'elle est entièrement formée par ces canaux et leurs cloisons. Ces dernières . . . . sont elles-mêmes criblées dans leur epaisseur par d'autres canaux aériens beaucoup plus petits. . . . . Ces canaux quelle que soit par rapport aux surfaces pleurétiques, l'inclinaison de la coupe sur laquelle on les observe, paraissent également variés de direction; le plus grand nombre, perpendiculaire aux surfaces, ou oblique, à section conique, et çà et là quelques uns, parallèles ou horizontaux, coupés en travers suivant leur longueur, et qui se presentent en forme de gouttière. Tous ces canaux sont très flexueux et s'abouchent aux extremités et sur leur contour les uns dans les autres par un grand nombre d'orifices. . . . . Aucun canal ne donne l'idée d'un cul-de-sac ou cœcum. Il n'en est pas qui ne soit ouvert au moins par les deux bouts, mais toujours en faisant un coude. Parmi les grands, presque tous reçoivent en outre, dans leur trajet, une ou plusieurs embouchures de canaux semblables. . . . . Enfin a leur interieur s'ouvre un plus ou moins grand nombre de petits conduits. . . . . Ces canaux . . . . donnent l'idée d'un espace très divisé à milliers d'embranchemens tortueux, incessamment continu avec lui-même, et où il n'y a rien de terminal, que l'orifice d'entrée, où se trouve egalement ramenée la sortie; c'est en un mot l'image d'un véritable *labyrinthe* . . . . ce qui m'a engagé à nommer ces conduits, *canaux labyrinthiques aërifères.*"—*Bourgery, Anat. Descrip. ou Physiol. art. Poumons.*

Addison makes some remarks on the bronchial ramifications in the fœtal lung, and then goes on to say, "It is important to remark, that there are no *anastomoses* to be seen between the intralobular bronchial branches; each branch pursues its own independent course, until it terminates in a closed extremity."*

In a work entitled *Soemmerings Lehre von den Eingeweiden*, published in 1844, and edited by Huscke, the pulmonary cells are described as little blind sacs, or cœcal, bladder-like branches, of the ultimate ramifications of the mucous membrane, which are sent off on all sides from the finest branches of the air-tubes. They are described as not communicating with each other, and as having closed extremities like other glandular structures.†

---

* *Addison, Philosophical Transactions*, 1842.

† "Lungenbläschen sind die Acini der Lungen und mit dem Lungen-Capillarsysteme bedeckt. Es sind die letsten blinden und blasenförmigen Zweige der Schleimhautverästelung, Blindsäckchen, die von dem letsten feinsten Luftröhrenzweige nach allen Seiten abgehen, aber nicht unter einander zusammenmünden, auch nicht in die Raüme des umgebenden Zellgewebes oder das

Eichholz, 1845. In the *Archiv für Anatomie und Physiologie von* Müller, 1845, some observations on the lungs will be found by this author. He objects to the process of inflation, and thinks that any compound gland treated in a similar way would present a similar appearance to the lung. His examinations were made on pieces of recent *normal* lung placed under the microscope. He has some valuable remarks on the structure of the air-cells, and considers that they are destitute of ciliated epithelium, but lined with cells, resembling very much liver-cells.

Rainey. In a paper read before the Royal Medical and Chirurgical Society, in March, 1845, this author enters into a description of the minute structure of the lungs. He says, "They are made up of bronchial tubes, bronchial intercellular passages, and air-cells. . . . They (the bronchial tubes) ramify in the substance of the lungs, their cartilaginous rings gradually disappearing; and, in the human lung, having arrived within about one-eighth of an inch of its surface, the membrane also terminates, but somewhat abruptly; after which, the passages conducting the air continue in the same direction as the bronchial tubes of which they are the continuation, but without having any perceptible membranous lining, their parietes being formed merely by the air-cells between which they pass, and by which they are surrounded. . . . The diameter of the ultimate bronchial tubes is from one-fiftieth to one-thirtieth of an inch. They communicate with but few air-cells

Gefässystem übergehen, sondern abgeschlossen endigen, wie jede Drüsenschleimhaut."—P. 268; quoted from *Adriani*, Op. cit.

and at these communications their membranous lining is not continued into these cells. . . . .

"The bronchial intercellular passages are at first of a circular form, and, like the bronchial tubes, do not communicate with many air-cells; but, as they approach the surface of a lobule, the number keeps increasing . . . . the intercellular passage loses its circular figure, and becomes reduced to an irregularly-shaped passage, running between the air-cells, and communicating with them in all directions; lastly, having arrived close to the surface of a lobule, it terminates in an air-cell, which is not dilated, as stated by Reisseisen, but has about the same diameter as the passage of which it is the continuation."

He describes the air-cells as small, irregularly-shapen, and most frequently four-sided cavities, varying in size in different parts of the same lung; those which are situated close to the bronchial tubes, or intercellular passages, communicate with them by large circular apertures, whilst those which are placed further from these passages communicate with them through the medium of other cells. It is impossible to decide how many communicate together.*

Moleschott. In an essay written in 1845, this author endeavours to refute the opinion of those, who believed that the vesicles communicate with one another. In his examinations he used chiefly lungs inflated and dried. His observations were made on thin slices placed under the microscope.

---

* *Rainey, on the Minute Structure of the Lungs, Medico-Chirurgical Transactions*, vol. xxviii., 1845.

According to Molcschott, the vesicles adhere closely to the bronchial tubes, and do not communicate together. He subsequently remarks, "As the bronchial tubes become smaller and thinner, so do they pass off more and more at right angles. The terminations of the bronchial tubes themselves are distinctly dilated into vesicles, which are sometimes larger, and sometimes smaller, but occasionally so small that it cannot be admitted that there is any conspicuous dilatation." He says the air-tubes do not terminate as Reisscisen said, nor yet in culs-de-sac with dilated extremities, but that they are furnished with vesicles at their sides. He states that he has never been able to find one of the canals communicating with another in such a manner as can be called an anastomosis; nor does any opening exist in the vesicle except that by which it is connected with the bronchial tube, at its end or at its side.*

---

* "Quo minora ac tenuiora facta sunt (bronchiola), eo magis ad rectum accedentibus angulis a bronchiis prodierunt, ... bronchiolorum ipsorum termini distincte in vesiculas dilatantur quæ quum modo majores sint modo minores, interdum tam parvæ sunt, ut non adeo conspicuam nonnunquam esse dilatationem illam sit concedendum." — *Moleschott, de Malpighianis Pulmonum vesiculis*, Heid. 1845, p. 32.

"Minime ex iis, quæ ipse vidi atque illustrissimo dilectissimoque præceptori Henle comprobanti ostendi, Francisco Reisseisen assentiri possum, singulos ductus aëriferos cœcis, 'nec ampliatis' finibus terminari autumanti. . . . . Neque vero in solis terminis inveniuntur vesiculæ Malpighianæ. . . . . Nunquam tamen inter duas vesiculas talem canaliculum alteram cum altera jungentem invenire potui, qui *anastomosis* dici possit, neque alia apertura prædita est vesicula, quam qua cum bronchioli vel fine, vel latere cohæret."—*Ibid.*, p. 33, 34.

Rossignol. A very valuable treatise on the structure of the lungs was written by this author, in 1846. He adopted a new mode of preparation, which consisted in injecting the blood-vessels, and then carefully inflating the lungs and allowing them to dry slowly. He sums up his observations as follows:—The air cavities of the pulmonary lobule are formed, first, of the successive ramifications of the lobular bronchial tube—ramifications which pass in all directions, as well centripetal as centrifugal, cross each other in every way without ever anastomosing, become shorter and more numerous as they are derived from a higher order of division, and at last terminate by becoming suddenly dilated in the form of *funnels* (which he terms *infundibulums*); secondly, of a series of *alveoli*, which line the internal walls of the *infundibulums* (funnels), and of the last bronchial tubes which precede them.*

The bronchial ramifications thus, according to Rossignol, terminate in infundibula. "Each of these," he says, "represents a small sac, more or less conical in shape, having its internal surface partitioned off by numerous alveoli, having but one opening of communication with the external air. It is on a small scale the representation or the exact reproduction of the reptilian lung, and especially of that of the batrachians. So that the human lung, looked at in this point of view, may be defined as the assemblage or concentration of innumerable small lungs, like those of reptiles, and bound up together by means of a common bronchial tree." *

---

* "Les cavités aériennes du lobule sont donc constituées, 1°· par les ramifications successives de la bronche lobulaire—ramifications qui affectent toutes les directions aussi bien *centripètes* que *centrifuges*, s'entrecroisent dans tous les sens, *sans jamais s'anastomoser*, deviennent de plus en plus courtes et plus nombreuses, à mesure qu'elles proviennent d'un ordre de division plus élevé, et enfin se terminent en *se dilatant brusquement sous forme d'entonnoirs.* 2°· Par des séries d'alvéoles qui tapissent les parois internes des infundibulums, et des derniers tubes bronchiques qui les précèdent."—*Rossignol, Recherches sur la structure intime du Poumon de l'homme, et des principaux mammifères*, Bruxelles, 1846, p. 36.

Adriani, in 1847, wrote an inaugural dissertation on the structure of the lungs. His description of the arrangement of the ultimate pulmonary tissue I believe to be the most correct, except in one point, that has yet appeared. He adopts the name of infundibula, given by Rossignol to the last expressions of the bronchial ramifications, and describes them as sacculated by air-cells or *alveoli;* he also admits that *alveoli* exist laterally on the walls of the bronchial tubes, just before they terminate in the infundibula. He differs, however, from Rossignol with reference to the communication between the different infundibula. He says, "It becomes a most important question, whether the neighbouring alveoli, according to Rossignol, only communicate with each other by means of the branch with which they are connected, or whether they also communicate by other lateral openings. We consider the opinion of Rossignol without doubt false, since we have seen most minute, round, and elliptical apertures in other lungs, and most clearly in those of the common stag, by means of which a communication is established between neighbouring infundibula."*

---

* "Chacun de ces infundibulums représente un *petit sac*, de forme plus ou moins conique, à surface interne cloisonnée par de nombreuses alvéoles, n'ayant qu' une seule ouverture de communication avec l'air exterieur. . . . . Il est donc sur un plus petite échelle l'image ou la réproduction exacte du poumon des reptiles, et en particulier des batrachiens. En sorte que le poumon de l'homme envisagé sous ce point de vue, peut être défini comme l'assemblage, la concentration d'innombrables petits poumons, semblables à ceux des reptiles et reliés entre eux au moyen d'un grand arbre bronchique commun."—*Ibid.*, p. 37.

Kölliker has some very valuable remarks on the lungs in his "Microscopical Anatomy." In speaking of the air-vessels and cells, he says, "With them (the bronchial tubes) are connected the ultimate elements of the air-passages — the air-cells or pulmonary vesicles — not, as was formerly believed, by each finest bronchial twig terminating in a single vesicle, but always by their communicating with a whole group of air-cells. These groups of vesicles correspond to the smallest lobules of racemose glands, and consequently there is no occasion whatever to designate them under any other name, as was done by Rossignol, who calls them infundibula, although it must be allowed that their structure in many respects is peculiar; for whilst in other glands the vesicles, if not quite so isolated from each other as has hitherto been supposed, still enjoy a certain degree of independence, the pulmonary elements corresponding to them—the air-cells—are, to a considerable extent, confluent with each other; so that all the vesicles belonging to one lobule open, not into ramifications of the finest bronchial twig going to it, but a common space, from which the air-vessel is afterwards developed." He says that the vesicles always open in such a way, one into the other, and coalesce to such an extent, as in the aggregate to form most usually a pyriform sacculus, with sinuous walls. These sacculi, identical with the finest lobules or the *infundibula* of Rossignol, must not be regarded as sacs furnished in their walls with closely placed cells or *alveoli;* the latter, on the contrary, being always grouped in such a way that many of them do not open directly into the larger space, but first into other *alveoli*, and through them into the common cavity.*

---

* "Jam quæstio est gravissima, num alveoli vicini uti Rossignol voluit, inter sese communicent tantum ope rami, cui adhærent, num etiam aliis ostiis lateralibus; hanc autem Rossignollii sententiam sine dubio falsam esse invenimus, quum et in aliis pulmonibus, et luculentissime in iis Cervi Elaphi aperturas minutissimas, rotundas et imprimis ellipticas viderimus, quarum ope communicatio inter infundibula vicina patebat."—*Arius Adriani*, *Dissertatio anatomica inauguralis de subtiliori Pulmonum structurá*, 1847, p. 41.

Schultz published in 1850 an essay on the lungs, which is chiefly devoted to the consideration of their structural anatomy; he, however, seems to have examined with care the arrangement of the ultimate pulmonary substance. He considers the air-canals as consisting of two portions,—the apparatus for conveying the air to and fro, and the true respiratory apparatus. He divides the ramifications of the trachea into bronchi, bronchia, and bronchiola. The latter terminate where the respiratory apparatus begins, which consists of the continuation of the bronchiola with alveolated walls, and the dilated and sacculated extremities of the tubes, previously called infundibula. That portion of the bronchiola which is sacculated he calls the *petiole.* His description generally accords with that of Rossignol; like him, he does not admit that the infundibula communicate together, except by means of the bronchial tube; and he attacks the opinion of Adriani.*

---

* *Kölliker*, *Manual of Human Histology*, translated by G. Busk and T. Huxley. Vol. ii., Art. Lungs.

Williams. — In the Cyclopædia of Anatomy and Physiology, article "Lungs," published in 1855, Dr. Williams has given a short sketch of the various opinions held with reference to the structure of the lungs, and has made some very valuable remarks of his own observations. In speaking of the minute anatomy of the lobule, he says, "the passages in which the bronchi end are greater in diameter than the bronchi themselves. Their sides are at first *smooth*, like those of the bronchial tubes; they become afterwards loculated with cells or alveoli, like the terminal air-cells. The intercellular passages," (Rainey — another word for infundibula) — "are those *continuous* channels in the lobule which are laterally sacculated by cells. They conduct the air to and from every part of the lobule; they give rise to secondary passages, which again lead to a third,

---

* "Non minus fere omnes auctores, hucusque in hâc commentatione laudati, consentiunt, etiam infundibula inter se non communicare, nisi per ramulum communem, ex quo exorta sint." After quoting Adriani's opinion, previously given, he adds, "Ingenue profiteor, me quoque loca ejusmodi, quibus communicatio inter infundibula vicina perficeretur, omnino nusquam vidisse."—*Schultz, Disquisit. de Structura et Textura Canalium Aeriferorum,* 1850, p. 10.

&c., all communicating with a group of air-cells. The intercellular passages *unite* and *divide.* They thus intercommunicate; they run through the lobule at every angle; they are perforated at every point by secondary passages of varying lengths and directions, sometimes only by a deeper cell than ordinary."

Mandl. — In the two volumes of this author on the microscopical anatomy of the body, some valuable articles are to be found on the structure of the lungs; but that which appears in the second volume contains the results of the author's more important investigations, with respect to the intimate nature of the ultimate air-tubes. The method of preparation on which Mandl most relies, is the injection of the bronchial tubes with simple gelatine, and desiccation of the portion thus injected. From such a preparation he cuts a thin slice, which he moistens with water, so as to make it swell, and places it under the microscope. He describes the bronchial tubes as terminating in a number of cavities, which have depressions in their walls; these cavities he calls "terminal cavities," the depressions, "utricles" or "vesicles." He compares the assemblage of cavities connected with a terminal bronchial tube, with the entire pulmonary sac of the frog.*

Milne-Edwards. — In a work of this able physiologist recently published, the following remarks appear with reference to the arrangement of the ultimate air-tubes: "The bronchial tube, arrived in the interior of its lobule, changes its structure as well as its form, and is disposed of in the same way as we have seen that the trachea is disposed of, when, in the higher reptiles, it dilates to form the pulmonary sac. . . . . The bronchial tube presents a dilatation which has been taken by some observers for its terminal portion, but which is, in reality, only the central cavity of the lobulette, and which is continued under the form of a passage, with bulging or rather alveolated walls, and is soon identified with the surrounding cells, which result from the bulging (budding) of these walls, and the intercrossing of membranous partitions, which subdivide the peripheral or terminal cavities of each of these little systems." *

---

* *Mandl, Anat. Micros.*, tome ii., chap. vi.

In the previous sketch, the names and observations of many authors who have written on the lungs have been omitted; but the opinions I have quoted are sufficient to show what have been the views which have generally prevailed.

---

* "Le ramuscule bronchique arrivé dans l'intérieur de son lobule, change de structure aussi bien que de forme, et s'y comporte à peu près de la même manière que nous avons vu la trachée elle-même se comporter, lorsque chez les reptiles supérieurs ce tube se dilate pour constituer le sac pulmonaire . . . . la bronche présente une dilatation qui a été prise par quelques observateurs pour sa portion terminale, mais qui n'est en réalité que la cavité centrale du lobulin, laquelle se continue sous la forme d'un conduit à parois bossuées ou mieux alveolécs, et se confond bientôt avec les cellules d'alentour, résultant du bourgeonnement de ces mêmes parois et de l'entrecroisement de cloisons membraneuscs qui subdivisent les cavités périphériques ou terminales de chacun de ces petits systèmes."—*Milne-Edwards, Leçons sur la Physiologie et l'Anatomie Comparée*, tome ii., p. 325.

PART II.

GENERAL CONSIDERATIONS.

The function of Respiration, that by which oxygen is supplied to the body, and carbonic acid and other products are removed from it, is performed by all animals; but it is only amongst the so-called air-breathing animals, that the organs, set apart for the performance of this special purpose, are called lungs. In the following brief remarks with reference to the general arrangement of these organs, I shall confine myself to the consideration of them as they exist in terrestrial vertebrata.

In all the above-mentioned animals, independently of those parts which regulate the mechanical movements, we recognise two essential portions of the respiratory apparatus—

1st. A series of tubes or convective channels, more or less numerous, by means of which air passes to and from the true respiratory portion.

2nd. An organ which receives the blood and the air, in which a thin membrane intervenes between the two fluids, and which is in fact the seat of the respiratory process.

These essential portions of the respiratory apparatus constitute the lungs, which consist of membranous pouches, having a number of cavities connected with them, by which their interior is more or less sacculated. They are two in number, generally equally developed, but in some animals one remains more or less rudimentary. They are placed in the large cavity of the body which lodges the heart and the other important viscera, and are usually at some distance from that portion of the body, through the medium of which they receive the air, viz., the nasal and buccal cavities. In all air-breathing vertebrata, the nasal fossæ open behind into the posterior part of the buccal cavity, so that air can be received into the lungs either by the mouth or nostrils. In connection with these cavities, situated behind the base of the tongue, is the tube which leads to the lungs, and which is called the trachea, the anterior or upper part of which, usually enlarged, constitutes the larynx, or organ of voice. Sometimes this tube terminates in the lungs without division, but mostly it divides, sooner or later after its commencement, into two branches, which are called bronchi. The above tubes, together with their ramifications, constitute the convective channels before mentioned.

The true respiratory portion of the lungs consists essentially of a hollow sac or sacs, suspended at the extremity of the convective channels, receiving air from them, and having in their walls a plexus of blood-vessels, containing the blood to be acted on by the air. In its most simple form the vertebrate lung may be looked upon as a membranous pouch, lined by a delicate membrane, and supported externally by a tissue, possessed of considerable elasticity, and covered on its outer side by a serous membrane called pleura. In proportion as a more complicated organ is required, for carrying on more efficiently the respiratory process, so does the surface with which the air is brought in contact become more extended. This is effected by the number of membranous pouches becoming increased, and by each being divided by a number of partial partitions, formed by the internal membrane projecting into the cavity, so as to separate it into different compartments, all of which communicate with the general cavity. The different chambers or compartments thus formed, in their turn become more or less divided by partitions, and thus a sacculated or alveolated condition results. By this doubling, as it were, of the inner membrane of the lungs, a very large extent of surface is obtained in the higher forms of air-breathing vertebrata, a condition which is necessary for that perfect aëration of the blood which their various functions require.

In studying the anatomy of the human lung, it becomes essential, in order thoroughly to understand its nature, to examine the condition of the organ as it exists in the lower forms of air-breathing vertebrata; a few observations carefully made of the lungs of some of these animals, prepare the way for the investigation of the more complex, but still fundamentally the same, structures in the mammalia; and I cannot too strongly recommend the adoption of such a course to all who are either engaged in original investigation, or are desirous of fully comprehending the subject herein discussed.

In the following pages I shall describe the several constituent parts of the lungs, the fœtal lungs, and the development of the lungs, in the order in which they will be found below.

I. The Pleuræ.
II. The Trachea.
III. The Bronchi.
IV. The Substance of the Lungs.
V. The Bronchial Tubes.
VI. The Ultimate Pulmonary Tissue, or ultimate air-tubes.
VII. The Blood-vessels.
  a. The Pulmonary Artery and its branches.
  b. The Pulmonary Veins and their radicles.
  c. The Bronchial Vessels.
    α. The bronchial arteries.
    β. The bronchial veins.
VIII. The Lymphatics.
  a. The Lymphatic Vessels.
  b. The Lymphatic Glands.
IX. The Nerves.
X. The Fœtal Lungs.
XI. The Development of the Lungs.

I. The Pleuræ.

Number, &c.—Reflections and Relations—Right Pleura—Left Pleura—Line of Reflection below—Shape—Connections—Fibrous Septum between the thorax and neck—Structure of Pleuræ—Vessels—Uses.

The pleuræ are the serous membranes which envelope the lungs; they are two in number, one occupying the right, the other the left side of the thorax, each enclosing its corresponding lung. They are separated from each other in the median line by a space called mediastinum. Each pleura is an independent serous membrane, and, like all serous membranes, with the exception of the peritoneum in the female, forms a shut sac. It has two surfaces, a free and an adherent one; the former is smooth and glistening, looks towards the so-called pleural cavity, viz.—that space into which the serous exudation takes place, and into which, under pathological circumstances, effusions are poured,—and is, in fact, the surface from which such exudation and effusions occur. The adherent surface is connected by means of areolar, or connective tissue, more or less delicate in different parts, with the inner surface of the parietes of the thorax, the outer surface of the lungs, the pericardium, and other structures lying in the mediastinum. The different parts of the pleura take different names according as they are in contact with different structures; that part of the membrane which is reflected on the lung is called *pleura pul-*

monalis; whilst that which lines the inner surface of the walls of the thorax is called *pleura parietalis;* that portion of the latter which covers the ribs and intercostal muscles being called *pleura costalis;* and that lining the upper surface of the diaphragm, *pleura diaphragmatica;* whilst that portion which is connected with the pericardium is termed *pleura pericardiaca.*

Behind the sternum, in front, and in front of the bodies of the vertebræ, behind, the two pleuræ approach each other, and in some parts, to be hereafter mentioned, join, being connected together by a small quantity of areolar or connective tissue, and then diverge; by their divergence they leave between them a space which is termed *mediastinum*, in which are situated the heart and other important structures, and which is denominated, in different parts, anterior, middle, and posterior mediastinum.

Reflections and Relations.—If the pleura of either side be examined, its uninterrupted continuity can be readily ascertained. Suppose the examination to be commenced at any given spot, by following any one direction we shall, after traversing the extent of the membrane, be brought to the same spot again. Commencing, then, at the junction of the ribs with their cartilages, we trace the pleura outwards and backwards, covering the ribs and intercostal muscles with their vessels and nerves, and opposite the tubercles of the ribs, the trunk of the sympathetic nerve. We find it also covering the branches which go to form the splanchnic nerves, and on the right side the great splanchnic nerve itself; whilst on the left side the nerve lies somewhat under cover of the aorta. On reaching the sides of the bodies of the vertebræ, the pleura is reflected forwards on to the posterior part of the root of its corresponding lung; it thence passes backwards on to the lung, covering its posterior border, and thus reaches its outer surface, which it lines throughout, dipping down into the spaces between the lobes, and covering their contiguous surfaces. Having reached the anterior margin of the lung, the pleura passes backwards to the anterior surface of the root of the lung, which it covers, and from which it is reflected forwards on to the pericardium, the arrangement differing somewhat on the two sides (to be hereafter described); from the pericardium it passes to the posterior surface of the sternum, and then turning outwards, covering the mammary vessels and lymphatic glands, it reaches the cartilages and anterior part of the intercostal spaces, and covering these latter, it reaches the spot from which we began to trace it. If we trace the pleura downwards from the root of the lung, we find it reflected on to the upper surface of the diaphragm, the entire extent of which is covered by it, except where the pericardium is adherent to the muscle. If we examine the pleura at its upper part, we find it projecting into the neck, forming a pouch above the level of the first rib, to an extent varying from one to two inches. The pouch thus formed receives the rounded conical apex of the lung.

Extending from the lower end of the root of each lung, to the upper surface of the posterior part of the diaphragm, is a fold of pleura called *ligamentum* *latum pulmonis.* It consists of a duplicature of the membrane, triangular in shape, its base below towards the diaphragm, its apex above at the root of the lung. It is connected by one side with the posterior mediastinum, and by the other with the posterior border of the inner surface of the lung. Its connections with the mediastinum are as follows: on the right side it is attached to the posterior part of the pericardium and the esophagus; on the left, to the posterior part of the pericardium and the aorta.

Passing down between the pleura and pericardium, on either side are the phrenic nerve and its accompanying vessels.

The arrangements of the pleuræ do not exactly correspond on both sides.

In the majority of cases I have examined, I have found the right pleural cavity higher than the left, and this examination has now extended over a considerable number of cases.

THE RIGHT PLEURA.—The right pleura is reflected from the posterior surface of the sternum, in the median line, nearly vertically from below the middle of the first piece, to the lower extremity of the bone; above the middle of the first piece it diverges outwards, as it begins to form its pouch.

As the right pleura passes backwards it gains the pericardium, from the upper part of which it is reflected on to the termination of the left innominate vein, and superior vena cava; it thence passes on to the anterior and outer side of the right innominate vein, covering about half its circumference, partly separated from it by the phrenic nerve, which also separates it from the vena cava, the nerve passing on the anterior surface of that vessel; it then passes on to the outer side of the innominate artery, and, as it is traced upwards and outwards, is found to cover the under surface of the subclavian artery and vein, as far as the first rib, separated however from them, by a structure to be hereafter described. As the pleura passes backwards from the superior vena cava, it covers the pneumogastric nerve, and then passes on to the trachea, the right border of which it invests, as also the right side of the esophagus; from the latter structure it passes on to the anterior part of the bodies of the upper dorsal vertebræ, near their middle. It covers the vena azygos as that vessel passes up through the thorax, and where it turns forward to arch over the root of the lung.

From the middle portion of the pericardium, the right pleura passes on to the anterior part of the root of the lung, and having covered the latter, is reflected from the posterior part of the root on to the esophagus, and thence on to the right border of the aorta,—which, however, it only invests to a slight extent,—and the vena azygos; it here reaches the bodies of the vertebræ, and covers them on their right side.

The right pleura has a less extensive connection with the pericardium than the left, in consequence of the oblique position of the heart to the left side.

THE LEFT PLEURA.—The left pleura is reflected from the posterior surface of the sternum in the median line, vertically, from below the middle of the first piece of the bone, to the level of about the fourth costal cartilage; below this level, the membrane is sometimes reflected in an oblique line from the posterior surface of the cartilages of the three last true ribs, but frequently it continues its vertical direction to the lower end of the sternum, so that the two pleuræ are often in contact with each other, throughout nearly the entire extent of the sternum, separated simply by some areolar tissue and fat, with the remains of the thymus gland above. Above the middle of the first piece of the sternum, the left pleura, as is the case with the right, begins to diverge outwards to form its pouch.*

From the line above mentioned the pleura is reflected on to the pericardium, and above, on to the left side of the aorta, separated from it, however, by the phrenic nerve and its vessels, and more posteriorly by the pneumogastric; higher up it lines the outer side of the left innominate vein, and passes to the outer side of the left carotid artery, separated from it by the pneumogastric nerve; it covers the outer and under surface of the left subclavian artery, and the under surface of the subclavian vein, as far as the first rib, and behind the subclavian it invests the left side of the esophagus.

---

* In examining the arrangements of the pleuræ, as they are reflected from the posterior surface of the sternum, the ordinary way of opening the thorax is not sufficient. The line of reflection anteriorly cannot be ascertained, unless the chest be opened a short distance on either side of that line. The following process should be adopted: — The cartilages of four or five upper ribs, not including the first, should be cut through half an inch or so external to their articulation with the sternum, and the pleura divided; a portion of the cartilages and ribs should then be removed, leaving the sternum with a portion of the cartilages attached to it, and undisturbed above and below. If, now, the hand be introduced and passed to the median line, the line of reflection of the pleura will be readily ascertained. When the sternum and cartilages are removed, as in the ordinary way of opening the chest in *post-mortem* examinations, a space between the pleura is made to appear, whereas in reality no such space exists.

From the upper and posterior part of the pericardium, this pleura is reflected on to the anterior part of the root of the lung, and having covered the latter, it arrives at the posterior part of its root; it passes thence on to the descending thoracic aorta, which it covers on its anterior and left surfaces; from the aorta it passes on to the outer margin of the bodies of the vertebræ, to the anterior part of the heads of the ribs, and to the intercostal spaces in a line with them. At the lower part of the chest, where the esophagus is in front of the aorta, the former tube gets a slight covering from the left pleura.

LINE OF REFLECTION OF THE PLEURÆ BELOW.—The pleuræ are reflected from the lateral parietes of the thorax, and from the pericardium on to the upper surface of the diaphragm. The line of reflection from the parietes, beginning from behind, is at first downwards and outwards for a short distance, then nearly horizontally forwards, and lastly upwards and inwards to the median line.

The following is the usual line of reflection which the pleura takes, as it passes from the sternum and ribs on to the diaphragm, commencing in front:—From the lower end of the sternum, or ensiform cartilage, it passes on to the seventh costal cartilage, and runs for some distance (four or five inches) downwards and outwards behind it; it thence passes across the seventh intercostal space on to the eighth rib, which it crosses just at its junction with its cartilage; it then crosses the eighth intercostal space, and reaches the ninth rib, which it crosses about half an inch posterior to its costal end; thence it passes across the ninth intercostal space to the tenth rib, which it traverses about three quarters of an inch behind its cartilage; then it crosses over the tenth intercostal space to reach the eleventh rib, which is crossed about an inch from its cartilage; from the eleventh rib it passes across the eleventh intercostal space, and thence on to the twelfth rib, which it crosses about an inch and a half behind its costal end; from this spot it is reflected nearly straight across to the first lumbar vertebra, or the last dorsal; its line of reflection here being below the level of the last rib, in consequence of the oblique direction of that bone. The lowest part of the pleura is where it crosses from the eleventh to the twelfth rib.

The line of reflection is the same on both sides, except that on the left side it usually begins from the sternum at a little higher level than on the right.

Shape.—In shape, the pleuræ resemble the lungs. They are conical, with a base below, concave, and an apex above, covered in by a fibrous membrane, which will be subsequently described; their inner surface is hollowed, and their external surface convex. The base of the right is more concave than that of the left, and its apex usually reaches from half an inch to an inch above the level of the opposite one.

Connections of the Pleuræ.—The pleuræ are connected with the structures in the thorax through the medium of areolar or connective tissue, which differs in its character in different parts. In the mediastinal portions, it is coarse and loose; on the inner surface of the ribs and intercostal muscles, it is less coarse, and firmer; on the diaphragm, it becomes finer; and on the lungs themselves, it is of a finer and more delicate character than in any other part. In consequence of this difference in the arrangement of the connective tissue, the firmness of attachment of the different portions of the pleura differs very materially.

Mediastinal portion.—Here the adhesions are for the most part loose, and the membrane may be readily separated. A considerable quantity of fat is often found in the areolar tissue of this region. In some parts, the folds of the two pleuræ are closely united, as in the anterior mediastinum.

Costal portion.—The union here is somewhat firmer than that of the mediastinal portion; but still, if care be used, the membrane may be easily separated from its attachments. Fatty deposits are often found in this region, beneath the pleura, in connection with the areolar tissue; they raise the surface of the membrane above the level of the surrounding parts, and are analogous to the appendices epiploicæ of the large intestines. There is a strong fascia lying upon the intercostal muscles situated underneath this portion of the pleura.

Diaphragmatic portion.—This is much more closely and firmly connected with the structure on which it lies than are the forementioned portions. In the interstices between the fibres of the diaphragm, it comes in contact with the serous membrane of the abdomen, and the areolar tissue is the sole structure intervening.

Cervical portion. — By this I mean that portion of the pleura which lines the under surface of the fibrous partition, which separates the thorax from the neck. The membrane here is not very firmly adherent, and readily admits of separation.

Pericardiac portion. — This is attached by a finer connective tissue than the costal portion, but less so than the pulmonic portion. It can be dissected off with care to a very great extent. It is more easily detached above, below, and anteriorly; but laterally, especially in the middle, it is very firmly adherent, and very thin.

A varying quantity of fat is found between the pleura and pericardium; in some instances this amounts to a very considerable quantity.

Pulmonic portion. — This is remarkable for its thinness; it is with difficulty separated from the lung, unless the latter have been previously soaked in fluid for some time. It may be isolated by inflation. It is sufficiently transparent to allow the injected capillary blood-vessels beneath, as well as the ultimate air-tubes, to be seen through it.

In thickness and strength the pleura differs in different parts. The costal portion is the thickest and the strongest, the pulmonic portion the thinnest and weakest.

FIBROUS SEPTUM BETWEEN THE THORAX AND NECK. — Covering the upper part of the pleura, viz., the pouch which receives the apex of the lung, and, in fact, forming the upper wall of each lateral half of the thorax, is a fibrous structure, which has connected with it, more or less intimately, a portion of the scalenus anticus muscle. The lowest portion of that muscle, taking origin from the transverse process of the last cervical vertebra, passes downwards and gets attached to the first rib, behind the subclavian artery; it sometimes expands and forms a thin flattened tendon, which is closely connected with the membrane above mentioned, which seems at first sight to be derived from the muscle itself; with care, however, the expanded tendon can be dissected off the membrane, and the latter is then seen to be an independent fibrous structure, connected with the inner margin of the first rib, and the first dorsal vertebra, and internally blending with the fascia passing down from the neck with the blood-vessels, &c. It constitutes, in fact, an expanded membrane lying immediately above the pleura. The existence of this structure was first pointed out by Dr. Sibson, but he regarded it as a tendonous expansion of the scalenus anticus muscle itself. From repeated examinations of it, I believe it will be rarely found to be derived from the muscle, but to be arranged in the manner I have described.

STRUCTURE OF THE PLEURA.—The pleura is a thin semi-transparent membrane, strong, and possessing considerable elasticity. It resembles in its structure the other serous membranes of the body. It consists of—

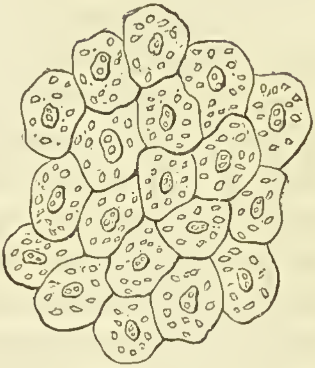
1. A tessellated pavement epithelium.

2. A basement membrane — according to some authors.
3. A lamina of connective or areolar tissue, which constitutes the chief strength and thickness of the membrane.

1. *The Epithelial Layer.*—This is situated on the free surface of the membrane; it is exceedingly thin, and consists of a single layer of flattened cells, which give a pavement-like appearance to the surface of the pleura, when examined with a sufficiently high power under the microscope. The cells are for the most part of a polygonal figure; but they vary much in shape, as well as in size. They are in contact with each other at their sides, and may be readily observed by gently scraping the surface of the membrane with a knife, and placing the matter thus removed under the microscope. Patches of the cells will be observed here and there, with isolated cells in other places. The cells are sufficiently firmly connected with each other for several of them to maintain their mutual attachment when scraped from the membrane on which they lie.

The epithelial scales or cells have a diameter varying from $\frac{1}{750}$ to $\frac{1}{1000}$ of an inch and upwards, the average being about $\frac{1}{1000}$ of an inch. They have a depth of about $\frac{1}{4000}$ of an inch; their greatest depth is at the centre, where the nucleus is situated. From the centre, or thickest part, they taper to their edge, as may be seen when the cells are placed on the latter. Each cell contains a nucleus of considerable size, more or less oval in shape, at or near its centre; and the nucleus often contains a nucleolus or nucleoli. The cells also usually contain a quantity of granular matter and fat globules. The addition of acetic acid renders the nuclei and the outline of the cells more distinct.

FIG. 1.*



2. *The Basement membrane.* — The existence of this membrane in connection with serous membranes, is regarded as doubtful by some observers. By Messrs. Todd and Bowman it is described as a continuous, transparent membrane, of excessive tenuity, apparently identical with that which supports the epithelium of mucous membranes.† By Professor Goodsir it is described as a germinal membrane.‡ Brinton, in his article, "Serous Membranes," in the Cyclopædia of Anatomy and Physiology, doubts the existence of the basement membrane, and says he has not been able to see it. As far as my own observations go, I am disposed to agree with Dr. Brinton, for I have never been able to satisfy myself of the existence of the membrane in connection with the pleura. I am not, however, on that account, prepared to deny its presence.

According to those who believe in its existence, the basement membrane is a thin, continuous, transparent membrane, placed between the epithelial layer and the connective or areolar tissue, which serves to support it.

---

* Fig. 1. Epithelial cells from pleura.

† *Physiological Anatomy.* Todd and Bowman.

‡ *Structure of Serous Membranes.*

3. *The lamina of connective or areolar tissue.*—This is the most external of the structures of the pleura, and forms the support for the basement membrane (if that membrane exist), and for the epithelium. Its inner surface is smooth and condensed, whilst externally it gradually merges into the subserous areolar tissue. It consists of white and yellow elastic fibres; the former exist in bundles, variously interwoven, and are mixed up with abundant reticulated elastic tissue. The fibres interlace each other in all directions, and many of them take a tortuous course. The sub-pleural areolar tissue, with which the structure just described identifies itself, exists in layers of varying thickness and density, proportionate to the degree of adherence existing between the pleura and the parts on which it lies. Like the areolar tissue elsewhere, it consists of bundles of white fibrous tissue, mixed with yellow elastic filaments; fatty matter is often found deposited in it, but this does not occur in that portion which covers the lungs; it is very frequently found in the costal portion, and has been previously alluded to.

Vessels of the Pleura.—The costal pleura is supplied with blood by the intercostal and other arteries, which ramify in the intercostal spaces; some small vessels are derived from them which form a plexus in the areolar tissue of the membrane. The diaphragmatic and mediastinal portions of the pleura, derive their supply of blood from vessels which are distributed to the structures on which they lie. With respect to the pulmonic portion, its supply of blood will form the subject of consideration, in the section devoted to the examination of the distribution of the bronchial arteries, and I must refer the reader to that part of the essay for further information.

Uses of the Pleura.—(Note.—In describing the uses of the different structures passed under review, I shall only mention the more obvious ones, which have reference chiefly to the mechanical movements of the lungs. Into the more particular functions of the parts it is not my province now to enter.)

One of the most important uses of all serous membranes, is to allow of free and easy movement of the parts which they clothe, on each other; thus, during the movements of respiration, when the lungs glide over the inner surface of the walls of the chest, it is necessary that the amount of friction should be as small as possible, and we consequently find that one of these membranes, secreting a lubricating fluid, is placed so as to envelope the outer surface of the lungs, and line those parts of the thorax over which the lungs glide. The pleura further serves to form a strong elastic external covering to the lungs, as well as to strengthen the thoracic walls, more especially the diaphragmatic portion. With reference to the further uses of this structure as a secreting organ, it forms no part of this essay to consider.

II. THE TRACHEA.

Its Nature — Situation and Extent — Direction — Dimensions — Shape — Mobility — Relations: of Cervical portion; of Thoracic portion — Structure: 1. Fibrous Coat; 2. Cartilages; 3. Muscular Fibres; 4. Elastic Tissue; 5. Mucous Membrane; 6. Glands; 7. Blood-vessels; 8. Lymphatics; 9. Nerves.

The *trachea*, or *wind-pipe*, or *aspera arteria*, is the common trunk of the air-tubes of the lungs. It is an elongated, symmetrical, contractile, and eminently elastic canal. It commences at the lower border of the larynx, and terminates at the commencement of the two bronchi, which in fact result from its bifurcation.

SITUATION AND EXTENT.—It is situated in the median line of the body, in front of the vertebral column, and extends from the lower border of the cricoid cartilage, opposite the sixth or seventh cervical vertebra, to the fifth or sixth dorsal vertebra, where it divides.

With reference to the relations of the trachea to the vertebræ, my observations do not quite accord with the statements of the authors I have mentioned below. I have never observed it in the adult commencing as high as the fifth cervical, nor terminating as early as the third dorsal vertebra. I have always found it commencing opposite the middle or lower border of the sixth or the upper or middle portion of the seventh cervical vertebra, and I have never found it terminate earlier than the fifth dorsal—the usual spot being at the lower border of the fifth, or the middle of the sixth. I have frequently found the angle of bifurcation opposite the middle of the sixth dorsal.

In the fœtus, before respiration has taken place, the first ring of the trachea is placed opposite about the fifth cervical vertebra, and the bifurcation takes place opposite the third dorsal. I have found this to be the case in several fœtuses I have examined. This will be again referred to.

Cruveilhier, Quain, and Harrison (Dublin Dissector) state that the trachea extends from the fifth cervical to the third dorsal vertebra; Bourgery states that the trachea extends from the fifth cervical to the third or fourth dorsal vertebra.

DIRECTION.—In the neck the trachea passes nearly vertically downwards, but as it passes from the neck into the thorax it bends backwards, taking the direction of the bodies of the vertebræ. In its course it diverges slightly to the right side, and at its termination it overhangs the right side of the bodies of the vertebræ. It seems to be pushed to the right side by the aorta and esophagus, which lie to the left.

DIMENSIONS: *Length.*—This has been variously stated at four to four and a half, or five inches: Quain, five inches; Harrison, Dublin Dissector, four to five inches; Cruveilhier, four to five inches; Bourgery, four to five inches; Schultz, three and a half to four and a half inches. I have found the average length of those I have examined about four and a half inches when unstretched, and when stretched about an inch longer.

Breadth.—The transverse diameter varies in different parts. It is sometimes a little constricted opposite about the third or fourth ring, and increasing from this spot to about the middle, it then narrows again, to increase again towards its bifurcation, which is the widest part. Sometimes it gradually increases in size from above downwards. The antero-posterior diameter does not differ much from the transverse; it varies slightly at different parts, depending upon the greater or less convexity of the tracheal rings.

The transverse diameter may be considered as averaging from nine to twelve lines in the adult male, and from eight to ten lines in the adult female, and the antero-posterior diameter as about the same.

The trachea is larger in the male than in the female.

The following are the dimensions given by different authors:—

Quain,	transverse diameter	¾	inch	to	1	inch,	
Harrison,	„ „	½	„	to	¾	„	
Cruveilhier,	„ „	10	lines	to	12	lines,	male.
„	„ „	9	„	to	10	„	female.
Bourgery,	„ „	10	„	to	12	„	male.
„	„ „	8	„	to	9	„	female.
„	ant.-post. diameter				12	„	male.
„	„ „	8	„	to	9	„	female.
Schultz,	transverse diameter	8	„	to	12	„	
„	ant.-post. diameter	7	„	to	9	„	

In an adult male of average size, the transverse diameter of the trachea, examined throughout, varied from nine to twelve lines, and the antero-posterior from ten to twelve lines.

SHAPE.—In shape, the trachea resembles a cylinder, a portion of which is deficient. Anteriorly and laterally, it is cylindrical; posteriorly, it presents a nearly plane flattened wall. About one-third of the cylinder is wanting. The external surface is rough and uneven in front and at the sides, and it presents, in the vertical direction, a number of elevations and depressions, the former corresponding with a number of cartilages of which the trachea is composed, and the latter with the membranous intervals between them. The convexity of the trachea is usually less at the upper than at the lower part—an arrangement adapted to prevent it becoming prominent in the neck.

MOBILITY.—In consequence of its mode of connection with surrounding parts, as will be hereafter described, the trachea enjoys very free lateral movement, the slightest pressure at once displacing it; this is essential to the maintenance of the proper calibre of the tube in the various movements of the head and neck.

RELATIONS.—The trachea is situated partly in the neck, and partly in the thorax; it will therefore be necessary to examine its relations in both regions.

a. The cervical portion.—In this I include that portion which lies above the level of the episternal notch.

The integument covering the trachea is thin; immediately beneath it is a thin fascia, the superficial fascia of the neck, and in it some small vessels are seen. A few muscular fibres (the anterior portion of the platysma myoides), very pale and thin, are sometimes found under this fascia, covering slightly the lateral portions of the trachea. These fibres are so pale and delicate that in ordinary dissection they are removed without being noticed. Beneath the fascia and the muscular fibres a quantity of loose fat and cellular tissue exists, with some small vessels ramifying in it, chiefly veins. The anterior jugular vein, when it exists, is seen at this stage of the dissection, running down on either side of the trachea, and a small vein from the upper part of the thyroid cartilage is sometimes seen crossing the upper rings of the trachea, to join the anterior jugular. Underneath the fat and areolar tissue is the fascia covering the muscles, a portion of the deep cervical, which forms a line between the two sterno-thyroid and sterno-hyoid muscles, called the *linea alba* of the neck. Beneath the fascia are the muscles.

The *sterno-hyoid* muscles are the most superficial: they do not always lie quite in front of the trachea, but to either side of it; sometimes, however, they are placed quite over the tube; this depends on their origin, whether from the sternum itself, in the median line, or more externally.

The *sterno thyroid* muscles are found beneath the last described; they cover the anterior part of the cervical portion of the trachea for about half an inch above the episternal notch; they then diverge, and pass to the sides of the tube, and above the point of divergence the trachea is covered by the thyroid gland, and some veins.

Beneath the sterno-thyroid muscles a plexus of veins exists, with a considerable quantity of loose areolar tissue and fat. The veins are the inferior thyroid, passing down from the thyroid gland; they lie upon the surface of the trachea, and terminate by joining the left vena innominata, either as a single trunk, which is occasionally seen, or as two or more separate vessels. In this situation the inferior thyroid artery of Neubauer, when it exists, is found. It arises from the innominate artery, and passes up, lying on the anterior part of the trachea.

The first ring of the trachea is superficial, covered only by the integument and fascia, and crossed by the ascending slip of the thyroid body, when it exists; the second and third are covered anteriorly by the transverse portion of the gland, and the four upper rings are embraced laterally by the lobes of the gland.

For about a quarter of an inch above the level of the episternal notch the arteria innominata, when it divides at its usual spot, lies to the right side of the trachea, as the vessel is passing upwards and outwards;* above the level of the division of the artery, the common carotid, enclosed in its sheath, lies to the side to the trachea, on a line with its posterior border; the vessel becomes deeper as it passes up, *i. e.*, farther from the anterior surface of the trachea, in consequence of the latter being dragged forward by the larynx. On the left side the common carotid occupies the position of the arteria innominata on the opposite side; it crosses the tube obliquely; higher up it occupies the position of the right carotid. The carotid artery is separated from the trachea by areolar tissue and lymphatic glands, and opposite the upper rings by the thyroid gland.

---

* The relations of the trachea in the lower part of the neck vary with reference to the innominate artery, depending upon the point at which the latter divides. I have seen it ascend an inch or more above the level of the episternal notch, passing obliquely across the trachea; and again, it often divides before it reaches as high as the notch, so as to have no relation at all with the cervical portion of the trachea. The variable position of the artery should always be borne in mind in operations for opening the trachea.

On the right side the recurrent laryngeal nerve passes up by the side of the posterior border of a few of the highest rings of the trachea, and branches from the nerve pass to the tube and enter its posterior border.

On the left side the recurrent laryngeal nerve runs up in the groove between the esophagus and trachea; branches pass from it, as on the opposite side.

Posteriorly the trachea in the neck is supported by the esophagus, and through the medium of it by the bodies of the vertebræ, covered by their muscles. The esophagus, even opposite the commencement of the trachea, projects slightly on the left side of that tube, and inclines more to the left as it passes down, so that, opposite the episternal notch, it projects three or four lines to the left side of the trachea; in consequence of this arrangement, the right posterior border of the trachea is unsupported by the esophagus.

On either side of the trachea a chain of lymphatic vessels and glands exists, and the tube is surrounded by a large quantity of loose areolar tissue; in fact, its connections with all the structures in contact with it, except the thyroid gland, take place through the medium of this tissue, which allows of great freedom of movement. The thyroid gland is connected with the trachea by means of a finer areolar tissue, and the gland partakes of all the movements performed by the trachea.

At its commencement in the neck, the trachea is superficial, and can be readily felt, but it gradually becomes more deeply seated as it passes down, and at its termination opposite the level of the episternal notch, its distance from the surface is usually about one inch and two lines, to an inch and a half, or sometimes more.

Length of the Trachea in the Neck.—I have found the following the average measurements of the trachea in the neck, under the varying conditions of extension mentioned. The averages are drawn from persons of medium height, and from males and females indiscriminately; in the latter, the proportionate length of the trachea in the neck is greater than in the former, in consequence of the smaller development of the larynx.

1. From lower border of the cricoid cartilage to the episternal notch, the body lying horizontal, from 1¼ to 1½ inch.
2. Do. do. the body horizontal and the head thrown back, from 1½ to 2 inches.
3. Do. do. the body raised at the shoulders, the head fully extended, . . from 2 to 2½ inches.

b. The thoracic portion.—In the thorax the trachea passes down in front of the vertebral column, diverging a little to the right side, apparently pushed in that direction by the arch of the aorta and the esophagus, which tend to the left; it is placed in the posterior mediastinum, between the two lungs, and is covered slightly on the right side by the pleura. It terminates usually opposite the fifth or sixth dorsal vertebra by division into the two bronchi; it is situated at its bifurcation opposite that part of the sternum which corresponds to the second intercostal space, and is distant from the posterior surface of the sternum about two inches, to two and a half or three inches.

In front of this portion of the trachea are the sternum, with a portion of the sterno-hyoid and sterno-thyroid muscles; the remains of the thymus gland and the areolar tissue and fat of the anterior mediastinum, together with some lymphatic glands. Crossing the tube, and resting upon it near its termination, is the transverse portion of the arch of the aorta, which lies in front and afterwards to the left side of it, passing from right to left, and from before backwards. Above the level of the aorta the trachea has the arteria innominata passing obliquely across it from left to right, the vessel being at first on its anterior aspect, and at its termination to its right side. The left common carotid artery, if it arise from the aorta close to the innominate, will cross over the trachea from right to left to reach its left side, along which it ascends; if it arise at some distance from the innominate, it will have but little relation with the anterior part of the trachea. Crossing in front of the trachea, superficial to the above-mentioned vessels, and nearly on a level with the upper border of the sternum, is the left innominate vein, and lying upon the anterior surface of the trachea, above the level of that vein, is the trunk, or the trunks resulting from the inferior thyroid plexus of veins.

On the right side the trachea has, placed in front and to the outer side of it, the superior vena cava, but it is separated from it by lymphatic glands and fat.

The right pneumogastric nerve passes down close to the right side of the trachea, and the cardiac nerve of the same side is for a short distance placed by the side of the tube, and then gets to its anterior surface.

On the left side the left subclavian artery, at its commencement, is sometimes in contact with the trachea, but it may arise behind it; it passes up for a short distance to the left side of the trachea, and somewhat behind it.

The left pneumogastric nerve is separated from the trachea by the left subclavian artery. The left recurrent, after passing beneath the aorta, gets to the posterior border of the trachea, and ascends between it and the esophagus.

The deep cardiac plexus lies on the anterior part of the trachea near its bifurcation.

Posteriorly the trachea is in contact with the esophagus, which separates it from the vertebral column; its right border overlaps the esophagus, and the latter projects to the left side of the trachea; a loose areolar tissue connects the two tubes together, and between them, at the lower part of the trachea, some lymphatic glands are sometimes found.

At the angle of bifurcation of the trachea, a strong ligamentous band is placed, which connects the two bronchi together, and limits their divergence from each other. This structure is triangular in shape, its apex situated above in the angle of bifurcation of the trachea, its base below free, and its two sides connected with the commencement of the two bronchi. In addition to this ligament, a lymphatic gland is generally found at this spot.

The trachea in the thorax is surrounded by a considerable quantity of loose areolar tissue and lymphatic glands; these structures are continuous with similar ones in the neck.

STRUCTURE OF THE TRACHEA. — The trachea consists essentially of a fibrous tube, in the layers of which are enclosed a number of imperfect cartilaginous rings. These rings are placed transversely to the long diameter of the tube; they are deficient behind, and their place is supplied by muscular structure. Lining the inner surface of the tube is a mucous membrane, in connection with which are numerous glands; immediately beneath the mucous membrane, yellow elastic tissue is found; and in addition to these structures there are blood-vessels, nerves, and lymphatics.

These several structures constitute the component parts of the trachea; each requires a separate examination:—1. The Fibrous Tube. 2. The Cartilages. 3. The Muscular portion. 4. The Yellow Elastic Tissue. 5. The Mucous Membrane. 6. The Glands. 7. The Blood-vessels. 8. The Nerves. 9. The Lymphatics.

1. *The Fibrous Tube.*—This is the most external

of the constituent parts, and occupies the entire circumference and length of the trachea. It forms the basis of the tube. It is attached above to the lower border of the cricoid cartilage, and at the bifurcation of the trachea it is continued on to the bronchi, and their ramifications in the lungs. In the intervals between the cartilaginous rings it exists as a single layer, as is also the case throughout the whole length of its posterior part, where the cartilages are deficient. Opposite each cartilage it consists of two layers, one of which passes on the anterior, the other on the posterior aspect of the cartilage. The two layers thus inclose the cartilage, as it were, in a distinct sheath, which may be dissected from it. The anterior layer is thicker and stronger than the posterior, and is more firmly adherent to the cartilage.

At the posterior aspect of the trachea the fibrous portion passes behind the muscular fibres, and is stretched across between the posterior extremities of the cartilages. It is thicker and stronger at its upper than at its lower part; at the former it has a distinctly yellow appearance, resulting from the presence of a large quantity of yellow elastic tissue.

This membrane is perforated by numerous vessels and nerves passing inwards to the deeper parts. The foramina produced by the entrance of these structures are distinctly seen, over the cartilaginous portion in the membrane lying between the rings.

When the trachea is fully stretched, the spaces between the cartilages become almost as long as the cartilages themselves, but under the ordinary conditions of the tube these spaces are much shorter.

Structure. — The fibrous tube consists of white and yellow elastic fibres, closely interwoven, and forming a membrane of considerable density. The yellow elastic element is most abundant at the upper part of the posterior wall, but throughout the whole extent it is extensively found.

Use. — The fibrous portion of the trachea undoubtedly acts as a basis by which the other structures may be supported; by it the cartilages are kept distinct and separate, and displacement of them is prevented; it forms a support for the muscular fibres and yellow elastic tissue, as well as for the mucous membrane; its arrangement allows of the elongation of the tube, and of its contraction by the muscular tissue; the presence of elastic fibres in it increases the general elasticity of the tube, and aids its function; further, it seems also to form a sort of ligament, by which the lungs are suspended from the base of the larynx.

2. *The Cartilages.*—Placed transversely one over the other, and separated by membranous intervals, are the tracheal cartilages. They vary in number from sixteen to twenty-one. In shape they very nearly resemble a horse shoe. Each cartilage forms a portion of a circle, and occupies from about two-thirds to three-fourths of the circumference of the tube. The proportion which the cartilages bear to the circle, of which they form a part, varies at different spots; at the upper part of the trachea it is usually greater than below, but as the size of the tube sometimes diminishes a little below its commencement, to expand again, this is not always the

case. The cartilages are deficient behind, and their place is supplied by muscular fibres, which pass transversely between their posterior extremities.

Each cartilage has two surfaces, one external, convex from side to side, and one internal, concave in the same direction. It has an upper and a lower edge, thin, and intimately connected with the fibrous structure where it splits, and two extremities, which terminate behind in blunt points, somewhat abruptly, and are neither inflected nor thickened.

The outer surface of each cartilage is flat, or nearly so, in the vertical direction; the inner surface is convex in the same direction; this is easily seen when a vertical section is made, and such section shows that the cartilage is thickest at its middle, and that it gradually tapers off above and below to its edges. In consequence of this increased convexity of the inner portion of the cartilages, and of the posterior layer of the fibrous tube covering them being thinner than the anterior, the cartilages are more prominent on the inner than on the outer aspect of the trachea.

Length. — The cartilages do not vary much in length in the same trachea. If their measurement be taken on their external surface in an average trachea, they will be found usually about two and one-eighth to two and a quarter inches long.

Their depth, or vertical diameter, varies from five-fiftieths to twelve or fourteen-fiftieths of an inch, the average being about seven-fiftieths, or about one-seventh of an inch; their thickness, or antero-posterior diameter, does not vary much, it averages about one-sixteenth or one-seventeenth of an inch.

Arrangement of the Cartilages.—There is no constant, uniform manner in which the cartilages are arranged. They are not of equal depth nor thickness, nor are they all placed parallel to each other. They occasionally bifurcate behind, and sometimes two or even three are partially united. Again, at times a cartilage extends only half round the tube, and may remain independent of those between which it is placed, or may unite with one of them. There are some peculiarities in the arrangement of the first and last cartilages. The first is broader than the others, especially in the median line, and is often connected with the cricoid cartilage. The last cartilage, placed at the bifurcation of the trachea, has its lower border prolonged downwards in the median line, and at the same time backwards, so as to form a spur-shaped projection between the two bronchi; from this process two semicircular cartilages are derived, each of which goes to form the commencement of a bronchus.

The last cartilage but one presents in the median line a projection downwards, and sometimes backwards, similar to that of the last, but to a much less extent; and occasionally the last cartilage but two has a slight projection downwards.

The posterior border of the cartilages usually projects farther back on the right side than on the left; this results from the position of the esophagus.

Each cartilage is inclosed in a fibrous sheath, previously described. The first cartilage is attached to the cricoid cartilage by means of the fibrous tube which descends from the lower border of the latter, and the continuation of the tube connects the cartilages with one another.

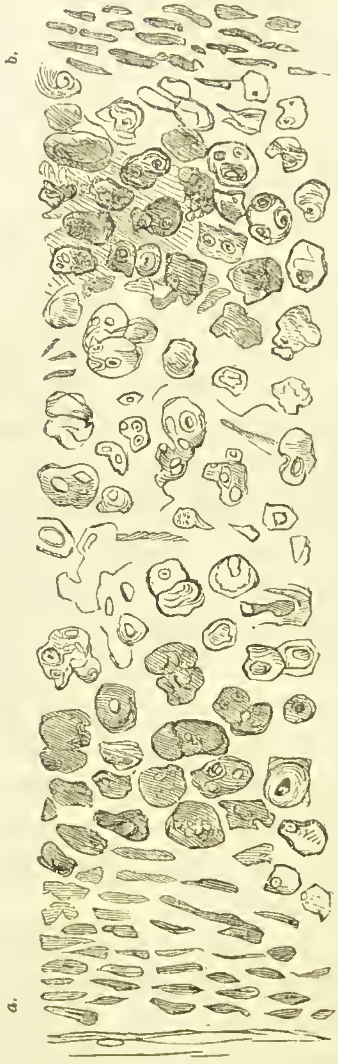
Perichondrium. — Underneath the fibrous sheath, enveloping each cartilage, is a delicate perichondrium; this is most easily seen and dissected off, when the cartilage has been soaked in water for some time; on the anterior part of the cartilage it is very intimately connected with the fibrous sheath.

Structure of the Cartilages. — The tracheal cartilages present no great peculiarity of structure; they are composed of cells lying in a matrix. The cells vary in size and shape, and contain nuclei, oil-globules, and granular matter. At the external border of the cartilages the cells are arranged parallel to the surface, transversely, and they are more numerous, smaller, and more oblong than in the interior. Towards the centre the cells become larger and more spherical, and less numerous and compact, whilst, as they approach the inner surface, they assume the shape and disposition of the external ones, but are not quite so numerous. Many of the cells, especially the more central ones, have distinct markings, giving them a double or even triple-like appearance. Acetic acid renders the outline of the cells more distinct, and brings the nuclei and granular matter more clearly into view. (Fig. 2, page 72.)

Structure of the Perichondrium.—This is composed of a very thin layer of white fibrous tissue.

Use of the Cartilages.—The cartilages form a most important part of the trachea; they tend to keep the tube always patent—a condition essential to the process of respiration; by their deficiency posteriorly they admit of the presence of muscular fibres, and in consequence of their shape and intimate structure, they are capable of being acted on by the muscles; they further possess an elasticity

Fig. 2.*



* Fig. 2. Sketch of a thin section of a tracheal cartilage, highly magnified. The cartilage cells are seen closely arranged and small at the surfaces, and larger and less numerous towards the middle. *a.* External surface. *b.* Internal surface. (Original.)

which enables them to accommodate themselves to the altered size or position of the tube, and to return to their original shape, when, from muscular action or other cause, they undergo a change in that respect.*

3. *The Muscular portion.*—At the posterior aspect of the trachea, where the cartilages are deficient, situated immediately beneath the fibrous coat, separated from it, however, in part, by the tracheal glands, is a layer of muscular fibres. These muscular fibres, or tracheal muscles, extend transversely, and nearly parallel to each other, between the posterior extremities of the cartilages, and across the spaces between the cartilages, in which situation they are attached to the fibrous tube. They consist of small fasciculi, and do not extend in a regularly horizontal direction from one extremity of a cartilage to the other; the fibres of different fasciculi occasionally run into each other; they pass somewhat obliquely, and sometimes from the extremity of one cartilage to the opposite extremity of the cartilage below. The fibres are not attached to the extreme ends of the cartilages, but to their inner surfaces, about half a line anterior to the ends; this, together with their oblique arrangement, gives them greater length, and therefore greater power.

The fibres are of a pale red colour; they form a layer of about one-fortieth of an inch in thickness.

---

* It has been stated by Williams and others that the tracheal cartilages manifest no disposition to ossify. In this opinion I cannot concur; I have rarely examined the trachea of an elderly man without finding the cartilages considerably ossified, and I have even found specks of ossification at a somewhat early period of life.

They are perforated by the ducts of the posterior tracheal glands, which are placed behind the layer of muscular fibres, between them and the fibrous coat.

The length of the fibres varies in accordance with the breadth of the membranous portion of the trachea. They are usually shortest at the upper part, and gradually increase in length towards the lower end, where they are longest.

Structure.—When examined under the microscope the fibres are found to be of the unstriped variety. They possess a faint outline, and have, interspersed throughout them, oblong nuclei of considerable size; these nuclei are rendered much more apparent by the application of acetic acid. The fibres, in addition to the nuclei, often contain granular matter.

Use.—The chief function performed by these fibres seems to be that of regulating the size of the tube in accordance with the quantity of air contained in it. If the trachea be dilated, the fibres will assist in restoring it to its previous shape, by acting on the extremities of the cartilages; their attachment somewhat in front of the ends of these structures, and their oblique direction, tend to increase their power.

4. *The yellow elastic Fibrous Tissue.*—Situated immediately beneath the mucous membrane is a layer of yellow elastic tissue. This layer is most apparent at the posterior part of the trachea, on the membranous wall. It exists there in longitudinal bundles of various sizes, some of them being as much as one-twelfth of an inch broad; they frequently have connecting fibres, by which they run into each other. In their course they do not take a perpendicular,

but a somewhat serpentine direction. At the upper part of the membranous portion these bundles are not so distinctly seen; the layer of elastic tissue exists, but is not formed into such definite bundles as it is below, although small bundles may be found. The bundles become very apparent about the middle of the tube, and they increase in size towards the lower end, and become largest at the bifurcation, and thence they pass into the bronchi. This arrangement of the tissue into bundles seems to be produced by the ducts of the tracheal glands passing between the fibres to reach the mucous membrane. These glands are most numerous below; the openings of their ducts exist in nearly vertical rows between the different bundles, and in reaching their destination the ducts separate the elastic fibres, and produce the fascicular arrangement.

In the cartilaginous portion of the trachea the elastic tissue exists as a layer of fibres, running longitudinally, as in the membranous portion, but not arranged in bundles, being uniformly spread out beneath the mucous membrane. In a trachea that has been soaked in spirit for a short time, the mucous membrane can be easily pulled off and this layer of tissue brought into view.

Structure.—The nature of the fibres composing this layer is at once seen if a portion be placed under the microscope; their curling extremities, and distinct outline, which is uninfluenced by the addition of acetic acid, prove them to belong to the yellow elastic fibrous tissue.

Use.—The presence of this tissue in the trachea renders the tube eminently elastic in the longitudinal direction, and provides for its return to its original length, after it has been elongated. It is more abundant on the posterior wall than elsewhere, in consequence of the absence of the cartilages in that region.

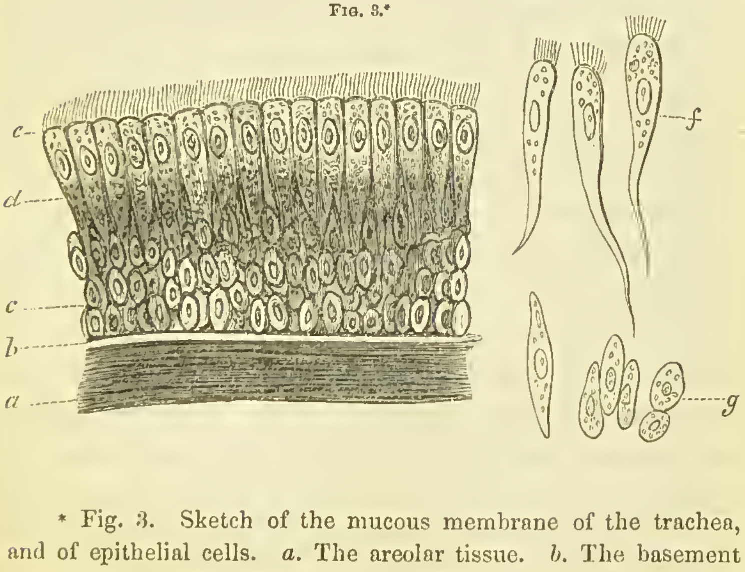
5. *The Mucous Membrane.* — The mucous membrane of the trachea is continuous above with that lining the larynx, and below it passes into the two bronchi, and is thence continued into the lungs. In a state of health it is of a pale pink colour, perfectly smooth, and nearly transparent. It adheres tolerably firmly to the structure beneath it.

Structure.—In structure it resembles other mucous membranes, and consists of: — 1. An Epithelium. 2. A Basement Membrane. 3. Areolar Tissue.

1. *The Epithelium.* — This consists of a layer of ciliated columnar epithelia, composed of several laminæ, and having a thickness of $\frac{1}{500}$ to $\frac{1}{400}$ of an inch. The superficial lamina consists of cylindrical cells surmounted by cilia, whilst the deeper laminæ are composed of cells not yet mature, which are more or less oval or elongated in shape, being more elongated as they are placed nearer to the free surface.

The ciliated epithelial cells consist of elongated club-shaped bodies, having an average length of $\frac{1}{650}$ to $\frac{1}{1000}$ of an inch, and a breadth of $\frac{1}{4000}$ to $\frac{1}{3600}$ of an inch. They are broadest at their free surface, from which they taper to their opposite extremity, and this is mostly pointed, and often prolonged into a slender tail-like process, sometimes of very considerable length. Some of the cells are very much elongated; I have seen them occasionally measuring as much as $\frac{1}{500}$ of an inch, half of which was made up by the tail-like prolongation. The cells are surmounted by cilia, which have an average length, according to Valentin's measurements, of from $\frac{1}{4000}$ to $\frac{1}{2500}$ of an inch. My own measurements have given an average length of $\frac{1}{5000}$ of an inch. In the epithelial cells, which are not unusually prolonged at their pointed extremity, the cilia are generally about one-fourth or one-fifth of the length of the cell itself. The line of attachment of the cilia with the cells is very distinct; they are very numerous, and are placed very close together; according to Valentin, the average number on each cell is from ten to twenty-two. Williams says each cell carries about fifty. (Fig. 3, *f*.)

FIG. 3.*



---

* Fig. 3. Sketch of the mucous membrane of the trachea, and of epithelial cells. *a*. The areolar tissue. *b*. The basement membrane. *c*. The deep layers of epithelial cells. *d*. The super-

The cilia consist apparently of very thin and delicate prolongations of the membrane of the cell. They are slender and conical in shape, arising from the cell by a broad base, and gradually tapering to their free extremity; they are transparent, and very soft; they possess a homogeneous structure, and do not exhibit any appearances of a fibrous or granular character.

The epithelial cells vary much in their dimensions, both in length and breadth; they are all furnished with a distinct nucleus, which contains a nucleolus. They further contain a quantity of granular matter and particles of fat. Valentin mentions that a double nucleus exists in some cells. I have found the nuclei to have an average long diameter of from $\frac{1}{2000}$ to $\frac{1}{3500}$ of an inch.

The deeper cells are smaller than the superficial ones; they are more or less oval in form, and are not furnished with cilia; their nucleus is less distinct than that of the larger cells; they contain granular matter. Their diameter varies from $\frac{1}{2500}$ to $\frac{1}{1500}$ of an inch. (Fig. 3, *g*.)

The epithelial cells, with their cilia attached, are easily seen by gently scraping the mucous membrane, and placing the matter removed under a moderately high power in the microscope. If a thin vertical section of the entire mucous membrane be made, in an animal recently dead, the epithelium will be seen *in situ* supported by the subjacent parts; and the

---

ficial cells, with *e*, their cilia. At *f* are seen some separate ciliated epithelial cells, and at *g*, some of the deeper non-ciliated ones. (After Kölliker.)

arrangement of the different layers of cells, and the cilia on their free surface, may be observed, together with occasionally a divided mucous follicle. (Fig. 3.)

The Basement Membrane.—Situated beneath the epithelial layer is a homogeneous structure, in which the deeper portions of the mucous membrane terminate. It consists of a layer of apparently structureless membrane, which is universally spread over the areolar tissue. It is transparent, and excessively thin, but admits of demonstration with no great difficulty. It is analogous in its character to the basement membrane of other mucous tissues. (Fig. 3, *b*.)

The Areolar Tissue.—The deepest portion of the mucous membrane is formed by a layer of areolar tissue, which serves to support the basement membrane, and constitutes that part of the structure in which the blood-vessels ramify. (Fig. 3, *a*.) It consists of white and yellow elastic fibrous tissue, which is arranged in two layers, thus forming, as it were, two portions, a superficial and deep; the superficial portion is made up almost entirely of white fibrous tissue, the fibres of which pass chiefly in a longitudinal direction; a few yellow elastic fibres are found mixed up with them.

The deeper portion consists in a very large proportion of yellow elastic fibres, which are easily recognised under the microscope by their clear outline, and their tendency to curl at their ends. The fibres pass for the most part in the longitudinal direction.

6. *The Tracheal Glands.*—A large number of

glands is found in connection with the mucous membrane of the trachea; they are of two kinds —

a. Smaller glands, which are chiefly found in the anterior walls.

b. Larger glands, found in connection with the membranous part of the tube, and in the spaces between the cartilages.

a. The smaller glands, or glandules, belong to the order of minute racemose glands; many of them, however, are of a very simple character, and form simple follicles, with a single or bifurcated extremity. They may be occasionally seen laid open, when a section of the mucous membrane and a tracheal cartilage is made, perpendicular to the surface, and the knife divides one of them; the inflection of the membrane forming the walls of the follicle, and its termination in a cul-de-sac, together with its lining of epithelial cells, may be distinctly seen. These follicles should also be examined in a trachea which has been soaked in spirit for a considerable time.

The small glands have a diameter of about one-tenth to one-fourth of a line; the opening made by them on the surface of the mucous membrane is somewhat oval in shape, longitudinally; this results apparently from the presence of the elastic tissue, the fibres of which take their course in the longitudinal direction, the ducts of the glands having to pass between them before they reach the surface.

These glands are very numerous, and are found spread over the entire extent of the mucous membrane, but they are most abundant in the localities I have mentioned.

b. The larger glands are found chiefly on the posterior part of the trachea. They are there situated behind the muscular portion, and a few may be found towards the lower end of the tube, embedded in the layers of the fibrous coat; it is, however, between the muscular and fibrous coats that these glands are found in largest numbers. They are very numerous, and in some parts form almost a complete layer; they are more numerous towards the lower than at the upper part of the tube. In addition to their situation at the posterior part of the trachea, they are also found between the cartilages, embedded between the fibrous and elastic coats.

These glands consist of little reddish, flattened, ovoid bodies, varying much in size, their diameter averaging from one-fourth of a line to a line, and even more; they belong to the compound order of glands, and the numerous offsets of which they are composed all terminate in a single duct, which passes between the muscular fibres, and may be traced opening on to the mucous membrane; the orifice they form is, like that of the smaller glands, longitudinally oval in shape. Each gland is invested by a thin fibrous sheath, resembling that investing the salivary glands.

In order to get the most correct notion of the number and mode of termination of the tracheal glands, the surface of the mucous membrane of a trachea, kept for some time in spirit, should be observed with a lens, or under the dissecting microscope. A large number of openings will be seen in it. These are of two kinds: first, smaller ones, scattered all over the membrane quite irregularly, but most numerous in the anterior part; and, 2nd, larger ones, most numerous on the posterior wall, and there placed in rows nearly vertical in direction, and lying between the bundles of yellow elastic tissue. The smaller openings belong to the small mucous follicles, the larger ones to the larger compound glands.

Structure of the Tracheal Glands. — The larger glands correspond in external character with the compound glands. According to Kölliker, they alone possess the usual tessellated pavement epithelium in their terminal gland vesicles, their ducts being lined by a columnar epithelium. The smaller glands consist of small, often bifurcated follicles, having a very thin wall, which is lined by a columnar epithelium. The cilia of the trachea are not prolonged into the gland ducts.*

7. *The Blood-vessels.* — *a. Arteries.* — The arteries of the trachea are derived chiefly from the inferior thyroid, from the subclavian. As this vessel passes upwards to reach the thyroid gland, it gives off branches, which pass inwards and supply the trachea and esophagus. These branches supply the different structures of the tube; some of them perforate the fibrous and muscular coats, and reach the mucous membrane, in the areolar tissue of which they terminate. They form a very fine plexus of capillaries, which presents the same appearance as that of the bronchial tubes, and will be described with those vessels.

---

* Schultz has described the large tracheal glands as so many vascular plexuses. — *Op. Cit.*

b. Veins.—The veins of the trachea are found chiefly to empty themselves into the inferior thyroid veins, and thus to reach the left innominate. The course of these veins, and their relations, have been described. Some of the veins at the lower part of the trachea pass downwards, and ultimately terminate in the veins at the roots of the lungs (bronchial).

8. *The Lymphatics.*—The lymphatic vessels of the trachea are numerous, and are found commencing in the mucous membrane. Kölliker states that he has seen them, in one instance, forming wide-meshed plexuses 0·003‴ to 0·001‴ broad, of thin-walled vessels, which gave off here and there isolated cœcal processes. The vessels all terminate in the deep cervical glands.

9. *The Nerves.*—The trachea is supplied with nerves from the pneumogastrics, the branches of which chiefly enter its posterior wall. Branches from the sympathetic accompany its vessels.

On the right side the recurrent laryngeal gives off a few branches, which supply the upper part of the trachea; they pass inwards between the esophagus and trachea, and enter the posterior border of the latter. In the thorax the trunk of the pneumogastric gives off branches to the lower part of the trachea, which is chiefly supplied by the nerve of this side. Small branches of the nerve pass forwards, and enter the trachea by passing through the spaces between the cartilages.

On the left side the recurrent laryngeal, hooking round the aorta, is in a position to furnish branches to the entire length of the trachea; and as it runs up between that tube and the esophagus, it gives off branches, which supply the trachea, in the same manner as on the opposite side. The branches it gives to the thoracic portion of the trachea are not numerous.

I am unable to state positively how the ultimate branches of the nerves end; they become lost in the substance of the muscular fibres and mucous membrane.

III. THE BRONCHI.

Number, &c. — Right Bronchus — Left Bronchus — Structure: Fibrous Tube; Cartilages; Muscular Fibres; Elastic Tissue; Mucous Membrane; Blood-vessels; Nerves.

The bronchi are the two tubes which result from the bifurcation of the trachea; they are called respectively, from their position and destination, right and left. They pass outwards, separating themselves from the trachea at an obtuse angle, to enter the substance of the lungs at their roots. Where they diverge, a strong ligamentous structure, previously described (at page 65), is situated, a structure which limits the extent to which they may be separated from each other.*

The two bronchi have certain points of resemblance to, and of difference from, each other.

In *shape* the bronchi resemble each other, and also the trachea. They are rounded in front and at their sides, and present posteriorly a flattened wall.

In *structure* the bronchi resemble each other, and they possess the same constituent parts as the trachea; these will be described farther on.

The bronchi differ from each other in *dimensions*, *calibre*, *direction*, and *relations*.

---

* Schultz has described a bronchial tube, as occasionally seen in man, derived from the trachea above its bifurcation, and passing to the upper lobe of the right lung. I have seen a branch of this kind in the lower animals, but never in the human subject.

The Right Bronchus is broader and shorter than the left; its average length is about an inch, its breadth or vertical diameter from eight to ten lines, and its antero-posterior diameter a little less. Its increased dimensions give it increased calibre over the left bronchus, and it is intermediate in this respect to the latter and the trachea. It takes a course obliquely outwards and downwards from its origin, and soon enters the root of its corresponding lung. It here generally crosses on a level with the sixth dorsal vertebra, and opposite about the junction of the third costal cartilage with the sternum. It passes above and on a plane posterior to the right pulmonary artery, and gets behind it; the vena azygos passes over it as the vein bends forward to empty itself into the superior vena cava.

The Left Bronchus is smaller, but much longer than the right; it is nearly double the length of the latter, and averages from eighteen lines to two inches. Its vertical diameter is about seven or eight lines, and its antero-posterior somewhat less. Its calibre is much less considerable than that of the right bronchus, in consequence of its smaller dimensions.

It takes a course obliquely downwards and outwards to enter the root of its lung; it crosses the level of the body of the sixth dorsal vertebra, and passes above the left auricle, and through the arch of the aorta, crossing obliquely in front of the esophagus, thoracic duct, and descending thoracic aorta; it is crossed in front by the left pulmonary artery, and then lies below it.

Both bronchi are in relation with the pulmonary plexus of nerves, and are surrounded with lymphatic glands, which in the adult and aged are usually of a dark colour.

The capacity of the two bronchi, taken together, is greater than that of the trachea.

STRUCTURE. — The bronchi resemble the trachea in structure; they consist of—

1st. *A Fibrous Tube*, which is placed most externally, is arranged in a similar way to that of the trachea, and possesses the same intimate structure.

2nd. *Cartilaginous Rings*, deficient behind, resembling those of the trachea in shape and ultimate structure. They vary in number, those of the right from three to five or six, and those of the left from eight to ten or twelve. They are not quite so regular in their arrangement as the tracheal cartilages, especially in the right bronchus, in which a junction of the cartilages takes place more frequently than in the trachea, either by their being joined at their extremities or in the middle. The cartilages form a little less proportion of a circle than those of the trachea, and the fibrous spaces between them are not so great as in that tube. I have found the depth and breadth of the cartilages about the same as those of the trachea.

3rd. *Muscular Tissue.*—This is arranged as in the posterior wall of the trachea; the fibres exist in bundles, passing transversely across between the fibrous coat and the elastic tissue, and are attached to the inner surface of the cartilages in front of their extremities.

4th. *Yellow Elastic Tissue.*—This is found all over the bronchi, beneath the mucous membrane. It is continued downwards from the trachea, and on the posterior wall it is arranged in large bundles, continuous with those of that tube; these bundles are separated from each other by the ducts of numerous glands, which pass between them. In the cartilaginous portion of the tubes the tissue is also sometimes arranged in bundles, which begin to form at the upper part of the bronchi, and become of considerable size, and well marked at their termination, whence they pass into the bronchial tubes; at other times the tissue is spread out uniformly over the cartilaginous portion, as in the trachea, and it is only towards the termination of the tubes that it begins to assume a fascicular character.

5th. *Mucous Membrane.*—This is a continuation of that of the trachea, and in every respect resembles it.

6th. *Glands.*—Numerous glands are found in the bronchi; they resemble in every respect those of the trachea, and are found in the same situations; they are—1st, the small glandules scattered over the mucous membrane throughout its whole extent, but being more numerous in the cartilaginous portion than elsewhere; 2nd, the larger glands, found behind the muscular fibres, between them and the fibrous coat, in connection with the posterior wall, and between the different cartilages, beneath the layer of elastic tissue.

7th. *Blood-vessels.*—The bronchi are supplied with blood partly by the vessels of the trachea, and partly by branches derived from the bronchial arteries. The plexus formed in their mucous membrane resembles that of the bronchial tubes in the lungs. The blood is returned from them through the medium of the bronchial veins, which empty themselves either into the vena azygos or the superior intercostal vein.

8th. *Nerves.*—The bronchi derive their nerves chiefly from the posterior pulmonary plexuses, which are formed behind them; on the left side some branches are sent off from the recurrent laryngeal, which are distributed to the bronchus of that side.

IV. THE SUBSTANCE OF THE LUNGS.

Constituent parts — Root of Lung — Situation — Relations — The Lungs — Situation — Form, Divisions, Size, &c. — Surfaces and Borders — Colour — Texture and Consistence — Elasticity — Weight — Areolar Tissue.

In speaking of the substance of the lungs, I shall include a description of the root of each lung, together with the general appearance, weight, colour, and conformation of the organ.

The substance of the lungs is made up of the ramifications of the air-tubes and their terminations; of the branches of the pulmonary arteries and veins; of the branches of the bronchial vessels; of nerves and lymphatics; of a quantity of connective or areolar tissue, surrounding these structures, and enveloping the different lobules; and, lastly, of a serous membrane covering the outer surface of the organ, which has been already described.

The several vessels and nerves above-mentioned enter or leave the lungs at one spot, which is called the root.

THE ROOT OF THE LUNG.—This name is given to the union of structures which enter or leave the substance of the lungs, at the spot where this entrance or exit takes place.

The parts of which the root of the lung is composed are the air-tube, or bronchus; the branch of pulmonary artery; the branches of pulmonary veins; the bronchial vessels; the branches of nerves; lymphatic vessels and glands. These structures are all joined together by connective tissue, and are enclosed in a sheath formed by the pleura. In consequence of this arrangement a kind of foot-stalk or root is formed, which serves the purpose of fixing the lung to the trachea and heart.

Situation.—The root of the lung is situated a little below the middle of the inner surface of the lung, and nearer to its posterior than to its anterior border. It is usually about two inches in depth, and an inch to an inch and a quarter in its antero-posterior diameter; it corresponds more or less completely with the fifth, sixth, and seventh dorsal vertebræ, usually extending from the middle of the fifth to the middle of the seventh, and is opposite about the middle third of the sternum, extending usually from about the level of the lower border of the second costal cartilage, where it joins the sternum, to about the level of the middle of the fourth costal cartilage, where it joins that bone.

Relations.—In front of the root, on both sides, are the phrenic nerve and the anterior pulmonary plexus, and behind is the posterior pulmonary plexus and the pneumogastric nerve. Below is the *ligamentum latum pulmonis.* On the right side, the superior vena cava and part of the right auricle lie in front of the root, and the vena azygos arches over it. On the left side, the root lies in front of the descending aorta and esophagus, and has the arch of the aorta bending over it.

The position of the great vessels in the roots of the lungs differs somewhat on the two sides. On both sides the pulmonary veins are lowest, and one of them most anterior; the pulmonary artery lies above the veins, and on a plane posterior to them, and anterior to the bronchus, which, together with the bronchial vessels, lymphatics, and lymphatic glands, is the most posterior of all. On the right side, the bronchus lies on a plane superior to the pulmonary artery; on the left, it passes behind it and gets below it.

The following is the relation of these structures as they are placed at the root of the lung:—

From before backwards, on both sides—Anterior pulmonary vein; pulmonary artery; bronchus.

From above downwards, right side—Bronchus; pulmonary artery; pulmonary veins. Left side—Pulmonary artery; bronchus; pulmonary veins.

THE LUNGS.—The lungs are essentially a single organ, but being divided into two portions, separated from each other, and situated one on each side of the thorax, they are considered as two in number, and are respectively called right and left.

SITUATION.—The lungs are situated in the thorax, which they in great measure fill; they occupy the two lateral portions of the region, and are separated from each other by the projection of the spine posteriorly, by the structures lying in the posterior mediastinum, and more anteriorly by the heart and great blood-vessels, together with the pericardium and the anterior mediastinum. Each lung is thus placed in a distinct and separate cavity.

Circumscribed by the boundaries of the chest, which affords them a protection from external injury, the lungs, together with the structures above enumerated, completely fill it, and during life and health are accurately adapted to its varying size, and constantly in contact with the inner surface of its walls; they are thus the chief cause of the size of the thorax, and at the same time are limited by it.

Protected laterally, posteriorly, and anteriorly by the osseous, muscular, and cartilaginous portions of the thorax, the lungs inferiorly rest upon the upper surface of the diaphragm, which separates them from the abdominal cavity; and superiorly they are in contact with the fibrous partition connected with the first rib (already described), which separates them from the region of the neck.

Each lung is free in every part of its extent, except at its root; it is, however, attached to the diaphragm by the fold of the pleura, already described. In consequence of this arrangement, the lungs are capable of being displaced, by effusions taking place into the cavity in which they are situated, by the development of tumours therein, or the presence of foreign bodies.

FORM, DIVISIONS, SIZE, ETC.—Each lung in shape resembles an irregular conoid, excavated on the inner side, broad externally, somewhat flattened anteriorly, and obtuse behind; the base, expanded, situated below, the apex, rounded, above.

The two lungs differ somewhat in form, size, and divisions. The right lung has a greater transverse diameter than the left, in consequence of the heart encroaching on the left side. The vertical diameter of the right lung is usually a little greater than that of the left, in consequence of it projecting somewhat higher in the neck. By vertical diameter I mean the length of its posterior border; and it will be found that both lungs, at the lower edge of their posterior border, are on the same level. This is well seen in a pair of healthy lungs removed from the chest and inflated; when measured they will be found of the same depth, provided the apex projects equally high on both sides. The vertical diameter of the right lung, taken from the apex to the centre of the base, viz., at its most concave spot, is less than that of the left, in consequence of the increased convexity of the diaphragm on the right side; provided always, that the apex of the right lung does not project so much higher in the neck than that of the opposite, as to counteract the effect of its increased concavity below.

Each lung is divided into lobes, of which there are two on the left side, an upper and a lower, and three on the right, an upper, a middle, and a lower. The lobes are separated from each other by interlobular fissures, which usually extend through the substance of the organ down to the root, but sometimes they are very imperfectly formed. The fissures do not correspond on the two sides. In both lungs there is a fissure, which usually runs downwards and forwards, beginning about two or three inches (sometimes lower in one lung than in the opposite one) below the apex, and terminating in the anterior part of the base; it cuts off an upper and a lower lobe. On the right side, from some part of this fissure, usually a little above the middle, another fissure runs forwards, almost horizontally, and cuts off a small middle lobe.

Many varieties are met with, with respect to the lobes; the fissures, and especially those of the middle lobe of the right lung, are sometimes only partially formed, and do not run down to the roots. Again, three lobes are found on the left side, and four on the right. Five, six, and seven lobes have been recorded, but such conditions are unusual, and rudimentary of that which is found in many lower animals, in which several lobes always exist.

SURFACES AND BORDERS. — In examining the configuration of the lungs, we have to consider their different surfaces and borders, their base and apex.

The External or Costal Surface. — Semicircular in outline, and placed in contact with the costal pleura, this is the most extended surface of the lungs. Smooth and irregularly convex, it is somewhat flattened anteriorly; laterally it is more convex, and it terminates behind in the obtuse posterior border. It is of greater depth behind at the posterior border than elsewhere, its vertical diameter diminishes as it passes forwards. The line of the different fissures is seen on this surface.

The Inner or Mediastinal Surface. — This surface looks towards the heart and great vessels, on which it is moulded. It is divided into three portions, — a superior, middle, and inferior. The superior is that portion situated above the root; it is formed by the inner surface of the upper lobe, and is slightly hollowed where it is moulded on to the trachea and great blood-vessels. The middle portion is occupied by the root, and is slightly hollowed for that purpose. The lower portion is that lying below the root, and is excavated for the reception of the heart, chiefly the ventricles. It is formed, on the left side, by the lower part of the upper lobe, and a small portion of the lower lobe; on the right side, by the middle lobe and part of the lower. The excavation is greater on the left side than on the right; and if a pair of lungs removed from the body be inflated, the cavity in which the heart is received will be well seen, and the expression which has been used, of *bed of the heart*, will be fully understood.

Anterior Border.—This border or margin is sharp and thin, and presents a sinuous outline. From the apex it passes downwards and inwards, and then nearly vertically downwards—on the right side as far as the lower end of the sternum; on the left to within about two inches of the lower end of that bone; it then alters its direction, and passes downwards and outwards, and joins the posterior border. The anterior margins of the two lungs converge rapidly above, and come in contact with the pleural septum of the anterior mediastinum, above the level of the heart; but opposite the ventricular portion of the heart, the anterior margin of the left lung recedes from the median line, and sometimes that of the right slightly, and thus a portion of the pericardium is left uncovered by the lungs.

Posterior Border.—Under this name is understood that portion of the lung which is received into the deep costo-vertebral groove, situated on either side of the spine. This border is very obtuse, and is moulded into the groove which receives it. It constitutes the thickest and deepest portion of the lung, extending from its apex to its base. At the inner side of this border there is a shallow groove running vertically throughout its entire extent; it corresponds with, and is produced by, the sides of the bodies of the vertebræ. This part of the lung is in relation, through the medium of the pleura, with the cord of the great sympathetic.

Base.—The base of each lung rests upon the upper surface of the diaphragm, and is moulded to its convexity. It presents a concavity, the most depending portion of which is found behind. The concavity of the right base is greater than that of the left, but the concavity, as seen in an inflated lung, is by no means great. The right base is more extensive than the left, its transverse diameter is greater; it is chiefly formed by the lower lobe, but anteriorly a portion of the middle lobe enters into it. The left base is formed in greater proportion by the lower lobe, about four-fifths, the remainder being formed by the upper lobe.

The base presents round its circumference a thin edge, which is not much elongated, being scarcely more than an inch in depth.

The lowest part of the lung is at the termination of the posterior border; from that spot the margin ascends both posteriorly and anteriorly.

The lower margin of the lung, as it is usually found after death, corresponds with a line drawn about an inch above the line of reflection of the pleura, from the diaphragm on to the parietes of the chest.

The Apex.—This is a rounded point, constituting the summit of the cone, which projects into the pouch formed by the cervical portion of the pleura, above the level of the first rib. It forms an obtuse process, which rises to a variable height in accordance with the height of the pleural cavity. It presents anteriorly two notches; one of which, situated about an inch or an inch and a half below the apex, is formed by the indentation of the first rib; the other, about three-quarters of an inch below the apex, is smaller, and corresponds with the course of the subclavian artery.

Colour.—In colour the lung varies according to age, the kind of death which has occurred, and the disease previously existing. In the fœtus, before respiration has taken place, it is of a reddish brown or liver colour, which becomes brighter on exposure to the air. In infancy and youth it is of a rose-pink colour, very pale in early infancy, and increasing in intensity as age advances. In adult life the lung becomes of a greyish colour, but still the pink colour often prevails to a considerable extent towards the lower part, resulting from the accumulation of blood. As old age comes on it assumes a darker tint, becoming of a slate colour, and sometimes even quite black. It is further marked by dark lines, which enclose polygonal spaces. These spaces are very numerous, and irregular in shape and size; they are very numerous towards the margins of the lungs; they are less distinct in the interlobular fissures than elsewhere; they are generally largest at and near the apex, smallest near the margins; they are usually darkest in the neighbourhood of the root. The dark lines which denote the boundaries of the lobules become darker with increasing age, as does also the substance lying between them, which is marked by a number of dark spots, which are produced by deposits beneath the pleura. These deposits are not only found at the surface of the lung, but in its interior also, in the interlobular tissue; they are generally tolerably abundant at the apex, but more especially so around the root, which region usually constitutes the blackest portion of the lung. The deposits are also found in the course of the bronchial tubes, and even in the air-cells. Large patches frequently exist underneath the pleura.

The nature of this deposit has not, so far as I am aware, been satisfactorily made out. It exists in very large quantities in the lungs of colliers, and those who follow similar occupations; it is of a carbonaceous character, and resembles that which is found in the bronchial glands, in which it often exists in large quantities.

This deposit does not exist in the fœtal lung, nor is it found in the lungs of infants; and if a healthy specimen of the latter be procured, and deprived as far as possible of blood, its colour will be found to be very pale, with a slight tinge of rose-pink.

Texture and Consistence.—In texture the lungs are soft, spongy, and yielding; they are the least dense of all the organs of the body. When handled they have a peculiar emphysematous feel, and when pressed the peculiar noise of crepitation is produced. If a healthy lung is cut crepitation is also heard, and a quantity of reddish frothy fluid exudes; this fluid consists partly of mucus from the air-tubes, and partly of serous fluid mixed with blood, and rendered frothy by admixture with air. The peculiar spongy character of the texture of the lungs, and the crepitation produced by handling or cutting them, result from the presence of air in their tubes. If pressure be used a part only of the air can be expelled, and even by means of the air-pump it is impossible perfectly to exhaust the air. This results, in all probability, from the smaller bronchial tubes collapsing, and thus preventing the air from escaping from the air-cells.

ELASTICITY. — In consequence of the abundant quantity of elastic tissue which exists in the structures composing them, the lungs are endowed with elasticity to an eminent degree. If the thorax of a living animal be opened, so as to admit of a sufficient quantity of air, the lungs immediately collapse to about a fourth or fifth of their previous size; and if they are inflated, and the air allowed to escape, collapse again takes place. It is by virtue of this elasticity that the lungs return to their previous size after each inspiration; and when we have considered the arrangement of the elastic tissue, in connection with the ultimate ramifications of the bronchial tubes, we shall understand how these receptacles of air are enabled to expel a portion of their contents after each distension.

WEIGHT.—In considering the weight of the lungs we have to remark on—*a*, The absolute weight of the organ; *b*, Its relative weight with reference to the entire body; and *c*, The specific gravity of its substance.

a. Absolute Weight.—The absolute weight of the lungs varies at different periods of life, and also from the varying quantities of blood, mucous, or serous fluid they contain, these being much influenced by the mode of death that has taken place. The differences existing in the weights of different lungs are so great, as to render any average drawn therefrom of but little practical value. My own observations in this respect have not been sufficiently extended to render them of much worth, and I shall therefore take the liberty of quoting the tables which have been drawn up by other authors.

Dr. John Reid has given a table of seventy-two cases (males), in which he took the weight of the two lungs, and he gives the following averages:—

Age.	No. of Cases.	Weight of Right Lung.		Weight of Left Lung.		Weight of Both Lungs.	
		oz.	dr.	oz.	dr.	oz.	dr.
From 1 year to 5 years	4	3	$11\frac{1}{2}$	2	$14\frac{1}{3}$	6	9
„ 5 „ 7 „	2	–	–	4	13	–	–
„ 7 „ 10 „	3	7	6	6	6	13	12
„ 10 „ 13 „	1	9	0	8	8	17	8
„ 13 „ 16 „	2	8	2	–	–	–	–
„ 16 „ 20 „	5	18	$4\frac{4}{5}$	14	14	33	2
„ 20 „ 25 „	4	22	$4\frac{1}{2}$	19	0	41	$4\frac{1}{2}$
„ 25 „ 30 „	6	24	12	21	10	46	6
„ 30 „ 40 „	9	22	$6\frac{1}{2}$	20	$2\frac{4}{9}$	42	9
„ 40 „ 50 „	12	27	6	23	6	50	12
„ 50 „ 60 „	17	27	2	22	$6\frac{8}{17}$	49	$8\frac{1}{4}$
„ 60 „ 70 „	4	25	$4\frac{1}{2}$	21	$10\frac{1}{2}$	46	15
„ 70 „ 80 „	3	22	$2\frac{2}{3}$	19	0	41	$2\frac{2}{3}$

He has also given the following table of forty females:—

Age.	No. of Cases.	Weight of Right Lung.		Weight of Left Lung.		Weight of Both Lungs.	
		oz.	dr.	oz.	dr.	oz.	dr.
From 1 year to 5 years	3	5	$2\frac{2}{3}$	3	7	8	$9\frac{2}{3}$
„ 5 „ 7 „	1	4	6	3	0	7	6
„ 7 „ 10 „	1	3	8	–	–	–	–
„ 10 „ 12 „	1	–	–	11	10	–	–
„ 16 „ 20 „	3	15	2	16	15	32	1
„ 20 „ 25 „	2	17	8	14	8	32	1
„ 25 „ 30 „	4	13	$15\frac{1}{2}$	11	6	25	$5\frac{1}{2}$
„ 30 „ 40 „	9	19	$10\frac{2}{8}$	15	$8\frac{2}{9}$	35	3
„ 40 „ 50 „	8	17	$15\frac{7}{16}$	16	0	33	$15\frac{7}{8}$
„ 50 „ 60 „	3	16	$8\frac{2}{3}$	20	$3\frac{1}{3}$	36	12
„ 60 „ 70 „	4	17	2	16	$7\frac{1}{2}$	33	$9\frac{1}{2}$
„ 70 „ 80 „	1	22	0	14	1	36	1

He remarks: "The weight of the lungs is so much modified by the quantity of blood which they may contain, that I have not attempted to ascertain their relative weight to the other organs. The right lung is almost invariably a few ounces heavier than the left; and it appeared to me that, when the left was heavier, this was dependent upon the greater quantity of blood contained in it."*

Mr. Hutchinson has given the weight of the two lungs in six females and fourteen males examined by him.

The six females varied in age from thirty to sixty-two years. He found the average weight of the lungs to be: the right, 19 oz.; the left, 17 oz.

The fourteen males varied in age from twenty-one to eighty years. The average weight of the lungs was: right, 30 oz.; left, 25 oz.†

---

* Tables of Weights of some of the most important Organs of the Body, &c. By John Reid, M.D.—*London and Edinburgh Monthly Journal of Medical Science*, 1843.

† *Cyc. of Anat. and Physiol., Art. Thorax.—J. Hutchinson.*

Quain gives the weight of the two lungs as ranging from 30 to 48 oz., the more prevalent weights being between 36 and 42 oz.; and he says that the proportion borne by the right lung to the left, is about 22 to 20.*

From Dr. John Reid's tables, it appears that the adult right male lung varies in weight from about 22 oz., the lowest average, to 27 oz., the highest; whilst the left varies from 19 oz. to 23 oz. The average weight of both together varying from 41 oz. to 50 oz.

In the adult female, the right lung varies in average weight from 14 oz. to 22 oz., and the left from 11½ oz. to 20 oz.; the weight of both together varying from 25½ oz. to 37 oz.

The weights given by Mr. Hutchinson, especially with regard to males, are greater than those of Dr. Reid; but as the observations of the latter were much more extensive than those of Mr. Hutchinson, they may fairly be looked upon as of more importance.

Meckel fixed the weight of the lungs at 4 lbs. Bourgery says they rarely exceed 2½ lbs.†

Relative Weight of the Lungs with reference to the Body.—As it is difficult to arrive at any correct average of the absolute weight of the lungs, so it is difficult to do so with reference to their relative weight to the entire body. Meckel fixed the average at one-fiftieth; Bourgery the same. According to Krause the ratio fluctuates between one-thirtieth and one-fiftieth. Quain gives as the average of twenty-five males and thirteen females, from tables drawn up by Reid and Hutchinson, one-thirty-seventh for the male, and one-forty-third for the female. Cruveilhier gives the proportion as one-thirtieth in the lungs of those who have breathed; Schmidt, after respiration has taken place, in the newly-born, one-forty-second, and Chaussier one-thirty-ninth.

---

* *Quain's Anatomy.*

† *Anatomie et Med. Operatoire, Art. Poumons.—Bourgery.*

Specific Gravity.—The specific gravity of the healthy lung is less than that of any other organ of the body, and much less than that of water. If ordinarily distended with air, it floats freely on the surface of water, and if fully distended, it rises almost entirely out of it. This lightness depends entirely upon the quantity of air which the organ contains, for if the air be exhausted, so as to leave the tissue undistended, it will sink in water.

The specific gravity of the lung varies from about 345 to 746—water being 1000. When fully distended with air, it has a specific gravity of about 126, and when deprived of air, according to Krause, of 1056.

Subdivision of the lobes of the Lungs into lobules.—Each lobe of the lung is an agglomeration of a number of small lobules, which represent the organ on a small scale. The structure and arrangement of the lungs are the same throughout; thus the minute examination of a lobule furnishes a correct notion of the anatomy of the lung. The lobules are found in every part of the lung, not only at the periphery of the lobes, beneath the pleura, but in the interior, grouped around the different vessels, which serve partially to support them, and placed in contact with each other. They are arranged almost in a similar manner to grapes on a bunch, for each is found in connection with a bronchial tube, which may be considered as its stalk. Each lobule is surrounded by others, and simply separated from them by a small quantity of areolar tissue, except where vessels intervene. The mutual pressure which results from this arrangement causes them to assume various shapes. In some animals they exist as tolerably well-formed, many-sided pyramids; their sides, plane, in contact with adjoining lobules; their apex corresponding with the point of entrance of the bronchial tube and vessels; their base broad and expanded at the opposite extremity. In man, their shape is very irregular; on the surface of the lungs they are seen with a square, or lozenge shaped, or polygonal base, beneath the pleura. In this situation they are flattened and thin, but in the interior of the lung they are less regular.

Each lobule is enclosed in a sheath, which consists of condensed areolar tissue, in which a large amount of the yellow elastic element is found. This sheath forms a perfect septum between the lobules, and isolates them from each other. On the surface of the lung, the lines which have been previously described mark the separation between the lobules; and that their sheath is a perfect and impermeable one, is seen by isolating a lobule in an inflated lung, which can be accomplished, with care, without the lobule collapsing. The line of demarcation is more apparent in the fœtus than after birth, and in the young than in the old.

Each lobule has entering it a bronchial tube, a branch of pulmonary artery, branches of bronchial vessels, and nerves. The pulmonary veins are not here associated with the other structures.

In some animals, as the cat, the subdivision of the lobes into lobules does not exist, whilst in others, as the calf, it is carried on to a very great extent, the lobules being very numerous, and some of them very small.

For an examination of the arrangement of the lobules of the lung, a portion which has been injected with wax serves very well.

THE AREOLAR TISSUE OF THE LUNGS. — This tissue exists in but small quantity in the lungs of man. It is found investing the various tubes, vessels, &c., which ramify in the substance of the lungs, and surrounding the different lobules. At the surface of the organ it is continuous with the subpleural areolar tissue. It is most abundant proportionately in the lungs of infants, and least so in old age. It usually contains, except in very early life, a quantity of pigmental deposit, which varies much in different individuals, but, as a rule, increases with increasing age. My observations on the fœtal lung tend to show that each pulmonary lobulette has its own separate sheath, and if so, it must be invested by a quantity of areolar tissue; this, however, is not discoverable in adult life. The areolar tissue enters the lungs at their roots, and accompanies their vessels and nerves. As I have before mentioned, the quantity is very small. It derives its nutrition from the branches of the bronchial arteries.

V. The Bronchial Tubes.

General Arrangement, Mode of Division, &c. — Shape and appearance — Alveoli — Structure: Fibrous Tube; Cartilages; Muscular Tissue; Elastic Fibres; Mucous Membrane; Glands.

The bronchi terminate in the roots of the lungs, and the divisions which result from them plunge into the substance of the latter; these divisions and their ramifications are called *bronchia*, or *bronchial tubes.* The right bronchus, in the root of the lung, gives off three branches, one destined for each lobe. It first divides into two branches, one of which (the smaller) goes to the upper lobe, the other passes downwards nearly vertically, and, after having given off a branch to the middle lobe, enters the substance of the lower lobe. The lower of the two divisions of the bronchus has a membranous portion behind, similar to that of the bronchi themselves, but this structure only exists as far as the giving off of the branch to the middle lobe.

The diameter of the branches derived from this bronchus is from four to five lines.

The left bronchus, as it reaches the lung, passes behind the pulmonary artery, and gives off a branch which passes outwards to enter the upper lobe; the other passes nearly vertically downwards, and lies between the anterior and posterior pulmonary veins. The lower branch is the larger of the two.

The diameter of these branches is usually about four to five or six lines.

ARRANGEMENT, MODE OF DIVISION, ETC., OF THE BRONCHIAL TUBES IN THE LUNGS.— Each lobe of the lung receives, as a rule, one bronchial tube, and this arrangement is rarely departed from, although other branches have been described by some authors, and sometimes do exist.* This branch results from the division of a bronchus. It may be termed the *lobular bronchial tube.* Having entered the substance of the lobe, it soon divides into branches; it may be found, after a short course from three-fourths of an inch to an inch, dividing into two or three branches of equal or nearly equal size, or it may give off one or more branches before its division, which is usually dichotomous, but very frequently not so. The branches given off from it pass in different directions towards the different parts of the periphery of the lobe. A branch larger than the others, the continuation of the trunk, may be found running through the centre of the lobe.

The *primary* branches, never numerous, pass from their tube of origin at more or less obtuse angles, according to the parts of the lobe for which they are destined ; they form a series of short branches, and usually terminate by dichotomous or trichotomous division, that is to say, by division into two or three branches of equal size. These divisions may be called *secondary* branches. The primary branches, before they divide, usually give off one or more lateral branches, varying in size. If the secondary branches are now followed out, they will be found to diminish gradually in size, and, after giving off lateral branches, to terminate by dichotomous division into what may be called *tertiary* branches; these tertiary branches, diverging from each other at an acute angle, and diminishing gradually in size, terminate in a similar way to the last, and from them result what may be called *quaternary* branches.

---

* In a right lung I examined, I found a small branch given off from the lower division of the bronchus, before it had fairly entered the lung ; it passed to the upper and back part of the lower lobe.

The dichotomous division is the mode of division which usually prevails; the trichotomous is much less frequent, but there is no great regularity in this respect. From all the branches, with few exceptions, whatever be their size, a greater or less number of lateral branches is almost invariably given off, and this obtains to the ultimate expression of the bronchial tubes.

The number of dichotomous divisions which take place, from the entrance of the bronchial tube into the lobe, to its termination in the tube which has connected with it the *ultimate ramifications*, varies, according to the distance of these latter from the point of departure of the lobular bronchial tube. I have found the fifth, sixth, seventh, and eighth divisions the last.

In following out a bronchial tube to its last division, we arrive at a point when it somewhat suddenly ceases. A description of the arrangement of one of these last tubes will serve for the description of all. The terminal twig of a bronchial tube is a small canal, which has, like all the divisions of the lobular branch, a number of openings in it; these are the orifices of very short tubes which lead to the *ultimate ramifications;* the canal, after giving off these short tubes, continues onwards for a short distance, preserving the same diameter until it terminates by a slight enlargement, into which opens a number of the *ultimate ramifications.* This enlargement constitutes the termination of the bronchial tube, and it is in this way that all the tubes end. This portion of the tube has a special character, which will be described further on.

I have mentioned above that from all the divisions of the lobular bronchial tube, branches are given off; these are more numerous in the smaller than in the larger tubes, and especially so in the last divisions. These branches proceed from different parts of the circumference of the tubes; they alternate like the branches of a tree, and the two contiguous ones are never seen taking their origin in the same line. Whenever a tube divides dichotomously, and the divisions resulting divide in a similar manner, the septum of the second divisions is always placed at a right angle to that of the first.

The branches derived from the first, second, and third divisions pass off from their trunks at angles more or less obtuse, but in the smaller tubes, where they approach their termination, the branches pass off at right angles, or at angles very nearly approximating thereto.

The openings of the larger tubes from their tubes of origin are more or less oval in shape, but in the smaller ones the openings of the branches which proceed from them are circular, and the openings gradually assume this circular shape as we pass from the larger to the smaller vessels. The circular openings have very much the appearance, as has been remarked by Rossignol, of having been made by a punch.

The larger branches of the lobular bronchial tube and its divisions pass in a nearly straight line to their point of termination, and are not bent at the spots where they give off branches; but the smaller divisions of the tubes, together with all the smaller branches, wheresoever they proceed from, become somewhat bent in their course; they are, in fact, bent at the points where they give off lateral branches. The flexion which exists in a fully distended lung is, I believe, very little, but in a lung that has been inflated and dried, it is very considerable; this results from the collapse of the lung substance during the process of drying, and must not be taken as indicative of the condition of the tubes during life.

Each lobule of a lobe has its separate bronchial tube, and the number of divisions which take place within it varies with its size; in general the divisions are few. The branch usually divides dichotomously as soon as it enters the lobule; it may, for the sake of distinction, be termed the intralobular branch.

The general arrangement of the bronchial tubes in the lungs, as regards their mode of ramification, resembles very much that of the branches of a tree; the dichotomous division, however, prevails extensively, but from nearly all the branches smaller ones are given off, which pass in the same manner as the branches of a tree.

The branches into which a bronchus, or a bronchial tube, divides, are always smaller individually than the parent trunk, but collectively they have a greater capacity, and this obtains as an absolute rule throughout the lungs. The bronchus of each side represents the apex of a rapidly increasing cone, the base of which is formed by the distal extremities of the ultimate bronchial ramifications.

Some authors have given different names to bronchial tubes possessing a different calibre. The larger ones they have called *bronchia*, the smaller ones *bronchiola*, but inasmuch as such a distinction seems to me to be attended with no practical benefit, and, as it places all above a certain size in one class, and all below it in the other, is of a perfectly arbitrary character, I have thought it undesirable to attempt to introduce an unnecessary definition, and have adopted the term generally used of *bronchial tubes*, to designate all the ramifications of the air-vessels within the lungs, as far as the commencement of the *ultimate ramifications*, or the *ultimate pulmonary tissue.*

Shape and Appearance.—As soon as the air-tubes enter the substance of the lungs, they become modified in shape; they lose their horse-shoe form, and become circular. This modification results from the alteration which takes place in their structure, an alteration rendered necessary in consequence of the position in which the tubes are placed. This subject will be referred to again.

On opening the bronchial tubes, their surface is found to be smooth and glistening; it is, however, in the larger tubes usually seen to be raised by narrow bands of fibres taking a longitudinal direction. As the tubes become smaller these bands disappear, and the surface becomes perfectly level. This condition is maintained until just before the termination of the tubes, when, by the aid of sufficient magnifying power, a number of depressions may be seen; these depressions, which will hereafter be described as *alveoli*, give a sacculated appearance to the walls. In the smaller divisions of the tubes, when their walls have become attenuated, the same appearance presents itself beneath their coats as beneath the pleura, when examined under the microscope: an appearance which is elsewhere described, and which results from the transparency of the membrane forming the walls allowing the outline of the "air-cells" which rest upon them to be visible. In the lungs of adults, and especially in the aged, a quantity of pigment is seen to be deposited beneath the smaller tubes, the coats of which allow it to be seen through them. In the lungs of infants this appearance is not observed, as no pigmental deposit usually exists.

Alveoli of the Bronchial Tubes.—The termination of each bronchial tube, as I have already stated, has a particular and special character. It differs in its anatomical arrangement from the other portions of the tube, and, no doubt, differs also in function; it constitutes, in fact, a part of the true respiratory system.

Rossignol was the first who pointed out the existence of a structure, at the termination of the bronchial tubes, similar to that which exists in the "ultimate pulmonary tissue" itself. He says: "In the bronchial divisions of the two last, and sometimes three last orders, it is plainly seen, when they are opened longitudinally, that their surface is covered over, or, as it were, honeycombed, by a number of small regular shallow cavities, placed side by side, and separated by thin perfect walls of the same height, which project into the interior of the bronchial tube." *

The existence of these bronchial *alveoli* has been noticed by subsequent observers. They may be easily seen in a lung injected, inflated, and dried, and sometimes even in one which has been simply soaked in spirit for a few days. They resemble the *alveoli* of the ultimate pulmonary tissue; they consist of little cup-like cavities, resting upon the bronchial tube, and opening into its cavity; they are surrounded by their walls, and their shape is more or less oval, or circular, quadrangular, or polygonal. In a preparation in which the pulmonary artery has been injected, branches are seen to pass from that vessel to these alveoli, before it reaches the *air-sacs* (air-cells).

---

* Dans les divisions bronchiques des *deux derniers ordres* et quelquefois *des trois derniers*, on voit avec evidence lorsqu'elles sont ouvertes longitudinalement, que leur surface est tapissée ou comme gaufrée *par une foule de petites cavités regulières peu profondes, rangées les unes à coté des autres et separées par des cloisons minces, entières, et de même hauteur qui font saillie dans l'interieur du tuyau bronchique.*—*Rossignol, Op. Cit.*, p. 29.

These *alveoli* are best seen in the lungs of some of the lower animals. In the cat they are especially distinct, and very easily recognised; in this animal they are found in the last ramifications of the air-tubes and their dilated extremity. In man, however, I have never seen them except at the extremity of the tube, and in many lungs I have examined, I have found no appearance of them at all. This is to be explained by the fact which has been pointed out by Rossignol, viz., that these *alveoli* diminish in number with advancing age. It would seem that as the lungs become more distended, these depressions or cavities become more and more obliterated. In the infant I have found the alveoli in the last bronchial tubes and their dilated extremities, but I have not found them in the penultimate and earlier branches, and even in the last branches they do not always exist previous to the dilatation. When the *alveoli* are found in the tube previous to the dilatation, they do not generally commence abruptly, but, being thinly scattered at first, their number gradually increases. As far as my observations go they are very rarely to be found in the adult, and never in the aged, except in the terminal dilatation.

It will be seen that my observations, as to the tubes in which these *alveoli* are found, do not quite accord with those of Rossignol, who places them in the two or three last divisions of the tubes, whereas I have never been able to find them except in the last. It seems to me probable that Rossignol has drawn his conclusions from observations on the lungs of the lower animals, in some of which, as, for instance, the cat, they exist to a greater extent than in man.

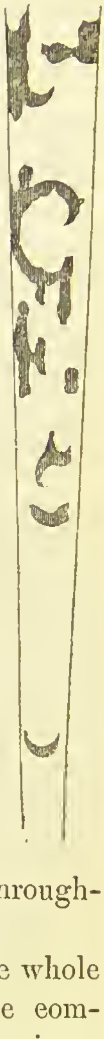
Structure of the Bronchial Tubes. — As the bronchial tubes pass from their parent tube, the bronchus, and plunge into the substance of the lungs, they become modified in their structure, and this modification continues to their ultimate ramifications. I have mentioned that an alteration takes place in shape, and this is the result of a change in structure, and the change in structure is destined to meet one of the requirements which exists. So long as the air-tubes are external to the lung, and are not subject to pressure on all sides, as is the case in the interior of the organ, the shape which they assume is eminently calculated for the function they have to perform; but when once they have entered into the lung, and are on all sides surrounded by lung tissue, it becomes necessary, especially in those branches which are placed in the centre of the organ, or near its root, that they should be so constituted that the shape and calibre of the tubes may be perfectly maintained, and that all parts of their circumference may be equally resisting. To effect this, the tubes assume a circular form, and their cartilages, instead of having the shape of a horse-shoe, and being placed regularly one beneath the other, so as to leave a membranous interval, are scattered throughout every part of the walls, and thus afford on all sides an uniform support. Were it not for this arrangement, the tubes might become more or less closed by the pressure of the lung substance, and thus the function of the organ seriously interfered with.

The same constituent parts are found in the bronchial tubes as in the trachea and bronchi, but they are not similarly arranged. We have: —

1. *The Fibrous Tube.* — This is a continuation of that of the trachea and bronchi. It exists as a layer of fibrous tissue surrounding the tubes, and enclosing the cartilages; it consequently consists of two layers in those tubes in which cartilages are found, opposite the seat of the cartilages; but in the spaces between them the layers are united. It is thick and strong in the larger tubes, but it gradually becomes thinner in the smaller ones, and in the smallest it assumes a condition of excessive tenuity.

2. *The Cartilages.* — These are enclosed in the fibrous membrane, in a similar manner to that in which the cartilages of the trachea and bronchi are enclosed; they are not found in all the bronchial tubes; in the smaller ones they are absent. They have not the regular shape and arrangement of those which exist in the bronchi or trachea, but consist of irregular, curved, more or less elongated pieces, distributed over every part of the circumference of the tubes; each piece forms a small segment of a circle. They vary much in their form, and are bounded by points and edges. In the largest bronchial tubes they are elongated transversely, and placed more as they are in the bronchi, but in the secondary and subsequent divisions they are placed very irregularly, and are elongated longitudinally. The cartilages do not cease abruptly, but, becoming fewer and fewer, they are at last only found at the points where lateral branches are given off, and in the smallest tubes they

FIG. 4.*



do not exist at all. In the larger tubes, wherever a branch arises, a cartilage is always placed, and in the largest vessels the cartilage forms two processes below, one of which belongs to each vessel of the division. The free margin of the cartilage, placed at the origin of an air-tube, is always concave and sharp, and is surmounted by a band of yellow elastic tissue. At the points of origin of the smaller air-tubes, the cartilages exist as thin semilunar pieces, with a sharp concave margin looking upwards; these becoming smaller, at length disappear. The cartilages are found as far as the *tertiary* divisions of the lobular bronchial tube, but not usually beyond. They are not found in the intralobular branch. (See Fig. 4.)

Structure.—In intimate structure these cartilages resemble exactly those of the trachea, but in the smallest of them the difference of arrangement and size, between the superficial and deeper cells, disappears, and the tissue becomes of the same character throughout.

3. *The Muscular Tissue.*—Throughout the whole extent of the bronchial tubes, as far as the commencement of the *alveoli*, a layer of muscular tissue is found, constituting one of the coats of the tubes. In the larger vessels, the fibres are found internal to

---

* Fig. 4. A smaller bronchial tube laid open, shewing the irregular shape and arrangement of the cartilages. (Original.)

the cartilages and fibrous coat, lying beneath the elastic fibres; in the smaller ones, after the cartilages and bands of elastic fibres have ceased, the muscular fibres are found lying beneath the mucous membrane.

The layer consists of bundles of fibres of the unstriped variety, which take a transverse or circular direction; in the larger air-tubes they are attached to the cartilages, but in the smaller ones they have no point of attachment, but are found taking a course round the tubes in small bundles, having distinct intervals between them. As the tubes become smaller the layer diminishes in thickness. I have traced these fibres into the ultimate bronchial tubes, and have no doubt of their existence there; they cease at the commencement of the alveoli.

Various opinions have been expressed with reference to the existence of muscular fibres in the ultimate bronchial tubes, and some authors, who admit their presence in the larger tubes, deny that they exist in the smallest. Rossignol states that they are not to be found in the last divisions of the tubes. Schroeder V. der Kolk has found them in the smallest tubes. Kölliker has seen them in tubes from $\frac{1}{10}'''$ to $\frac{1}{12}'''$ in diameter. Schultz and Adriani have not been able to find them in the smallest tubes. Henlé, on the contrary, states that the smallest bronchial tubes consist of an epithelium, a layer of longitudinal, and another layer of transverse muscular fibres, with a coat of cellular membrane. Williams says, "The walls of the minutest bronchi are composed of three coats, a mucous, a muscular, and fibrous."

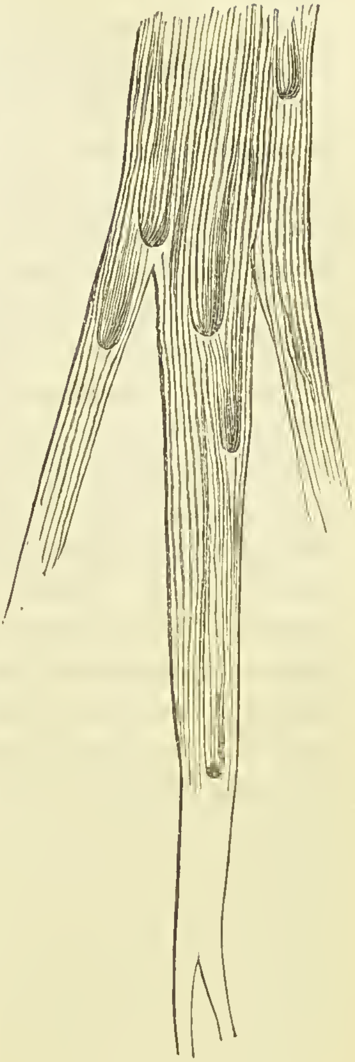
I have never been able to discover the longitudinal muscular fibres which have been described by Henlé, but I have always found, immediately under the mucous membrane, the transverse layer.

Morbid anatomy will often aid us in the investigation of healthy structure, and in some lungs this tissue will be found much increased in thickness; and in such specimens the layer of muscular fibres may be seen extending almost down to the termination of the bronchial tube, with the simple aid of a dissecting microscope.

It is not easy to demonstrate the existence of the muscular fibres in the ultimate bronchial tube, in a recent specimen of lung, inasmuch as it is difficult to remove the thin coat of the tube alone. I have often seen, in an inflated and dried lung, a number of transverse fibres in the bronchial tubes, reaching down to the termination of the tubes; an appearance resulting from the presence of the transverse muscular fibres.

4. *The Elastic Fibres.*—The elastic fibres of the bronchial tubes are continued downwards from those of the bronchi; they are arranged in very distinct bundles in the larger branches, and generally form projections on the surface of the tubes. Whenever a branch is given off, some of the bundles of the parent tube are continued into it, on its proximal side, but from the distal side of the commencement of the branch new bundles arise, which take their origin from the cartilage situated at the opening. The free margin of the cartilage is always surmounted by a bundle of elastic tissue; this bundle is derived from the union of two bundles, belonging

FIG. 5.*



to the parent tube, which arch across and join each other at the lower border of the opening. In the larger bronchial tubes the bundles are numerous; they gradually diminish both in number and size, and in the smaller tubes the fibres cease to have the fascicular arrangement. I have seen them in some lungs forming distinct bundles almost to the termination of the tubes, but in most healthy lungs I have not found them in those tubes in which the cartilages do not exist. (See Fig. 5.)

5. *The Mucous Membrane.*—This is a continuation of that lining the bronchi, and possesses the same constituents, but it gradually becomes thinner as the tubes diminish in size, until at length in the

---

* Fig. 5 represents a larger bronchial tube with its divisions laid open. It shews the bundles of elastic fibres, and the manner in which two bands unite to encircle the lower margin of each opening in the tubes. (Original.)

smallest ones it assumes a condition of excessive tenuity. It becomes continuous in the air-sacs with the membrane which lines the latter.

6. *The Glands.*—Two sets of glands are formed in connection with the mucous membrane of the bronchial tubes. 1st, The compound glands resembling those situated at the posterior aspect of the trachea and bronchi, but smaller in size; and, 2ndly, the small mucous follicles, which resemble those elsewhere described. The former are found lying between the cartilages, and do not exist in the smaller divisions of the tubes; the latter are spread over the mucous membrane, and are very numerous in the earlier divisions of the lobular bronchial tube; they gradually diminish in number towards the smaller tubes. I have been unable to trace them in the smallest divisions of the tubes, but in some preparations, especially where there has been inflammation, I have seen them in nearly the last ramifications. In structure these glands resemble those previously described.

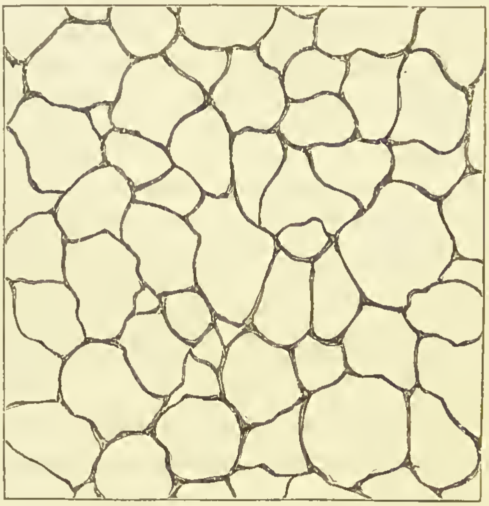
VI. The Ultimate Pulmonary Tissue.

Appearances presented by the Ultimate Pulmonary Tissue under various modes of examination — Termination of the Ultimate Bronchial Tubes — names given to the Ultimate Air-canals by different authors — the propriety of these names considered — the term used by the Author — the Air-sacs: their arrangement — the Alveoli: their arrangement and number — the propriety of the term Alveolus considered — the arrangement of the air-sacs in groups or lobulettes: the shape of the lobulettes — best method of demonstrating their arrangement — Do the Air-sacs communicate with each other? — Resemblance between the Air-sacs and the Pulmonary Sac of Batrachians — Structure of the Air-sacs and Alveoli; Elastic Tissue; Basement Membrane; Epithelium — Dimensions of the Ultimate Bronchial Tubes, Air-sacs, and Alveoli — Difference in Size of the Air-sacs at different periods of life — no difference in different parts of the Lungs — Mode of preparing the Lungs for examination.

Under this head I propose to consider that portion of the lung substance which has been generally known under the names of *air-vesicles* and *air-cells*, viz., the final divisions of the air-tubes.

If we take a piece of lung which has been dried, after being normally distended by inflation, and examine its external surface with a lens of sufficient power, we observe that within the markings which enclose the larger spaces, which I have previously described at page 98, there exists a number of lines, marking off a very large number of small spaces. These spaces vary much in size and shape, but for the most part are hexagonal. The surface of the lung between the lines *appears* to bulge slightly, and the lines themselves to form, as it were, shallow grooves between the raised portions; in fact, we have the appearance presented of a number of small irregular-shaped vesicles. The lines are not all equally distinct; some are very faint, others, again, are more strongly marked. (See Fig. 6.)

FIG. 6.*



If we examine the surface of a lung in which mercury has been poured into the bronchial tubes, we observe the globules of mercury filling the spaces above described, but instead of having the irregular outline alluded to, the spaces become, under these circumstances, more circular.

If we examine the surface of a lung which has been injected through the pulmonary vessels with some opaque material, and then inflated and dried, the appearance above described is by no means distinct, because, if the injection has run well, the whole surface of the lung is rendered opaque, and but little distinction can be observed between the vesicles themselves and their boundaries, for, as we shall presently see, the lines above described indicate the boundaries of the so-called "air-vesicles."

---

* Fig. 6 shows the appearance presented by a human lung (which was inflated and dried) on its pleural surface. The lines bounding the irregular-shaped spaces denote the boundaries of the alveoli and air-sacs, and no distinction can be seen between the walls of the sacs and alveoli. Drawn with the aid of the camera lucida. (Original.)

If, now, instead of proceeding further in our examination of a portion of uninjected lung, we take a piece in which the blood-vessels have been injected with some opaque material, the air-tubes inflated, and the whole subsequently dried, after the manner I shall hereafter describe, and cut a very thin slice from its surface, and then place the slice under the simple or compound microscope, so as to examine the *cut surface*, we find that it presents an appearance somewhat resembling that of a honeycomb, and we observe a number of small cavities, separated from each other by membranous partitions. These cavities are of various sizes and shapes; some of them approach the circular, but most of them are polyhedral. Enclosed within these cavities, viz., at their pleural end, are a number of small, shallow, cup-like depressions or cells, which are marked off, and bounded, by slightly raised partitions, so that a sacculated or *alveolated* appearance is observed; some of the partitions just mentioned are somewhat more raised than others. The cells, or depressions, or *alveoli*, formed as I have described, are irregular in shape. (See Figs. 7, 8, 9, 10.)

Fig. 7.*

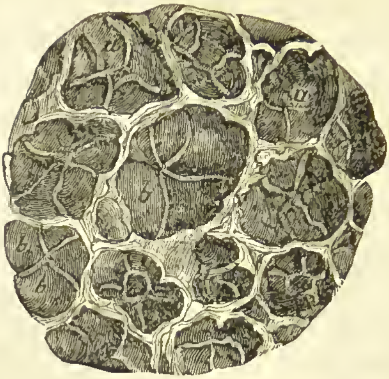
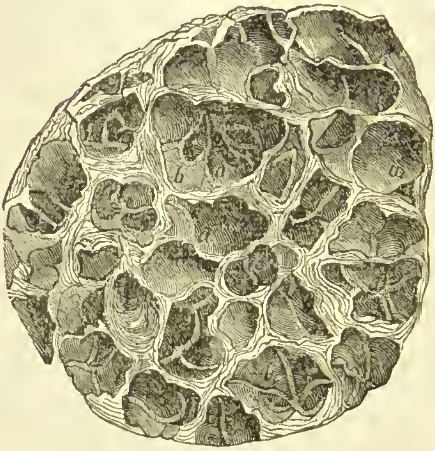


Fig. 8.†

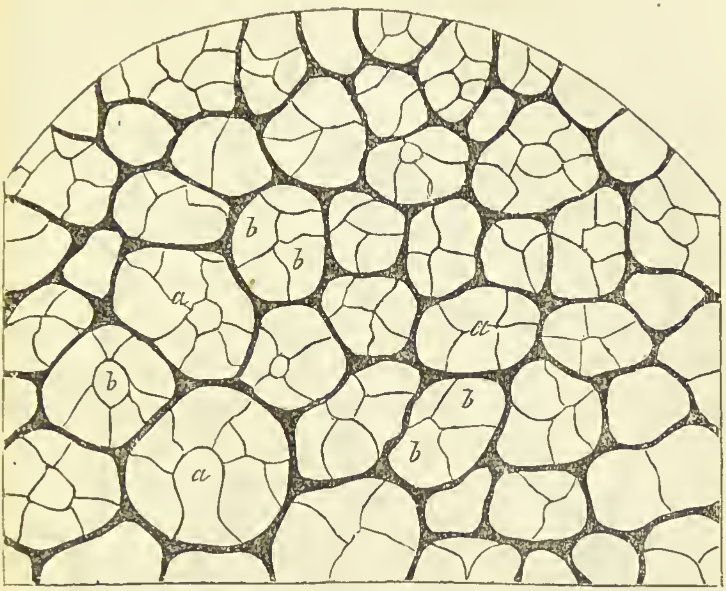


---

* Fig. 7 represents a very thin slice of a cat's lung (injected, inflated, and dried), from the surface of the lung. The eye is looking upon the cut surface. The depressions, *a. a.*, are the bottoms of the air-sacs, resting on the pleura. The light coloured lines that surround them are their walls, and the small depressions seen within the walls, *b. b.*, marked off by less distinct lines, are the alveoli. The specimen from which this drawing was made was a very good one, and the drawing may be considered as fairly representing the appearance presented. (Original.)

† Fig. 8 is a drawing of a similar slice to that of Fig. 7, taken from the human lung. *a. a. a.* are the air-sacs, *b. b.* the alveoli. The lighter portions represent the walls of the air-sacs and the alveoli. (Original.)

Fig. 9.*



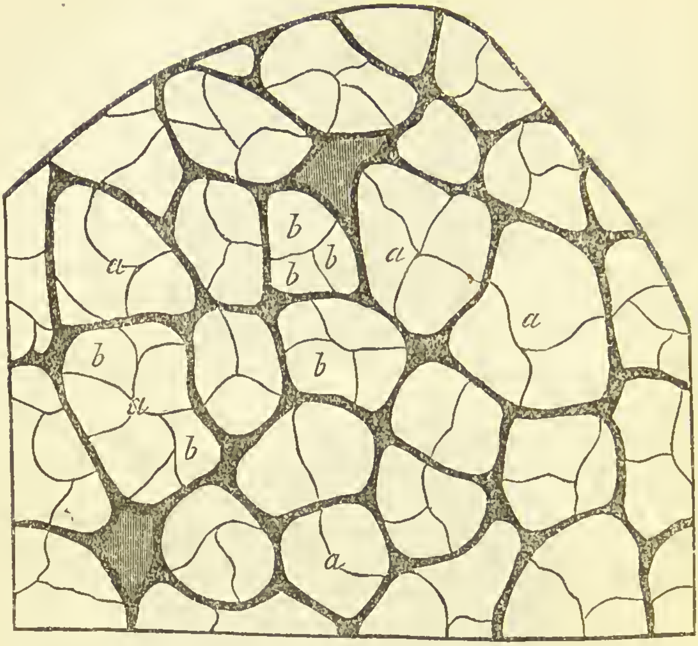
We further observe, that towards the margins of the slice we are examining, the same kind of depressions or cells exist, separated by similar partitions.

If, now, we examine a slice cut in a similar way, only *a little thicker*, we observe a number of elongated cavities which run in different directions, but for the most part are vertical, or slightly oblique to the surface of the pleura; we see that they are separated from each other by thin walls; and where one of them has been cut transversely, we find it is

---

* Fig. 9 represents a thin slice of a cat's lung, viewed in the same way as in the last two drawings. *a. a.* are the air-sacs, and *b. b.* the alveoli situated at their fundus. The dark lines are the walls of the air-sacs and alveoli. This drawing was made from a reflection of the object by means of a camera lucida fixed to a microscope; the outline of the walls of the air-sacs and of the alveoli was traced as it was thrown on the paper. (Original.)

Fig. 10.*



quadrangular or hexagonal, or more or less rounded or oval in shape. We further see that some of these cavities have been cut obliquely, and others more or less horizontally, and that the walls which bound them are sacculated, having in them a number of depressions, separated by projections of the membrane forming the wall into the interior of the cavities. We also observe that some of the cavities are flexed in their course, and occasionally we see in them circular, clearly defined openings; and if we pursue the investigation of these openings, we find that they lead to cavities consisting either of a small single sac, with very few alveoli, or else to a sac somewhat larger, with several alveoli in its walls; in fact, we find these openings leading to offsets from the cavity in which they are placed. On looking down the cavities above described, we find that some of them divide into two branches of equal, or nearly equal size.

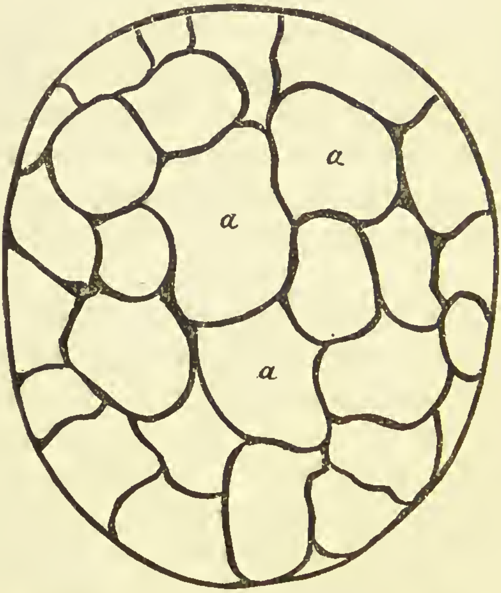
---

* Fig. 10 is a drawing of a thin slice of a human lung, drawn in a similar way to the last. It shews the same structure as the three previous drawings. *a. a.*, the air-sacs; *b. b.*, the alveoli at their fundus. (Original.)

If, now, we direct our attention to the portion of lung itself from which we have removed the larger of the two slices just described, we observe the cut open mouths of the cavities alluded to; we find that they pass more or less obliquely from the pleural surface; we see their sacculated walls; and we also notice, on looking at some of them which are favourably placed, that we can see the orifice of entrance into the cavity, and that it is circular, clearly defined, and contracted; we further observe that some of the cavities have been divided more or less horizontally, and that they seem to run for some distance nearly parallel to the pleura.

If we now make a thin section of a piece of lung, either injected, inflated, and dried, or simply inflated and dried, carrying the section in the direction of the surface of the pleura (the pleura, together with a small portion lying beneath, being first sliced off), and then place the slice under the microscope, we observe, in the section thus made, a number of openings varying in shape and size. Some of these openings are more or less circular, others oval, some quadrangular, and, again, others oblong. Here and there openings may be seen very small, with a circular or oval outline. All the openings are separated from each other by thin walls. The elongated or oblong openings in some instances present the appearance of a number of depressions in their walls, together with a number of pointed processes projecting into the interior of the cavity; in fact, the sides are *alveolated.* The oblong cavities sometimes show at one end an irregularly rounded extremity, having the appearance of the termination of a cana Some of the other openings, more especially the larger quadrangular and oval ones, also present the appearance of *alveoli*, just described, with respect to

Fig. 11.*



---

* Fig. 11 represents a thin slice, cut transversely, of the lung of the cat. It shows the shape of the air-sacs. This drawing was taken by means of the camera, in the same way as the last three. *a. a.*, are the cut air-sacs; the dark parts, their walls. (Original.)

the oblong ones. If the section has been made at a right angle to the direction of the canal, pointed processes will be often seen projecting into its cavity. Between some of the openings, portions of the walls belonging to other canals are seen, and a number of small depressions are observed in them, separated

Fig. 12.*

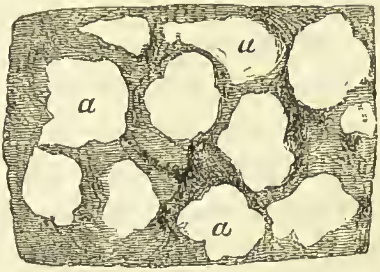
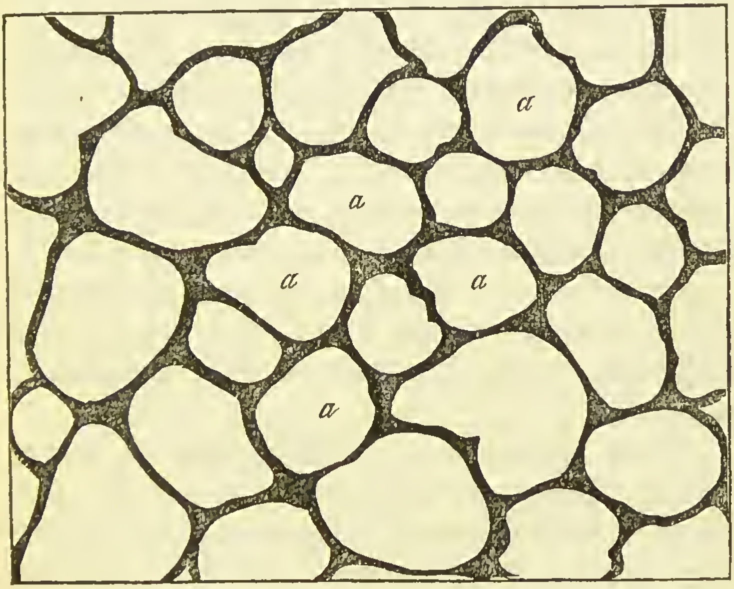


Fig. 13.†



---

* Fig. 12 represents a slice of a cat's lung, similar to the last. It was drawn as it appeared under the microscope. *a. a.*, are the air-sacs. (Original.)

† Fig. 13 represents a similar slice to the last two, of an infant's lung. Drawn from a reflection of the object by means of the camera lucida. (Original.)

by slightly raised membranous partitions. (See Figs. 11, 12, 13.)

We now pass on to explain briefly the objects which have just been described.

The elongated cavities which have been described in the previous pages are the ultimate branches of the air-tubes. The *alveoli* placed at the sides, and at the extremities of the cavities, are the so-called "air-vesicles" or "air-cells;" the openings described are the openings of the ultimate air-tubes, divided in some part of their course; the pointed processes mentioned are the projections of the membrane which forms the boundaries of the *alveoli;* and the depressions are the *alveoli* themselves. Where the openings are oblong, the tubes have been cut more or less longitudinally; where oval or quadrangular, more or less transversely. The parts which are described as existing between some of the openings are the *alveolated* walls of other ultimate air-tubes.

Having now mentioned the appearances presented by the ultimate air-tubes examined under certain conditions, I proceed to describe their arrangement more fully.

If we follow out a bronchial tube in a lung injected, inflated, and dried, and trace it to its termination in the ultimate air-tubes or cavities, by carefully removing the portions of lung which are upon it, and then the upper half of its wall, so as to lay bare its interior, we adopt, I believe, the best plan of ascertaining how the tube itself terminates, in what manner the cavities I have spoken of proceed from it, and what relation they bear to it. For this purpose we should expose a bronchial tube from its entrance into a lobule to its termination. We find that the bronchial tube, having entered its lobule, divides and gives off branches, and at last terminates in a dilatation, which has opening into it a number of orifices. (Figs. 14, 15, 16, 17.) These orifices lead to a number of canals, which have been variously designated, "intralobular bronchial ramifications" (Addison); "lobular passages" (Todd); "intercellular passages" (Rainey); "infundibulums" (Rossignol); "Malpighian vesicles" (Moleschott); "terminal cavities" (Mandl). These names seem to me to be all more or less open to objection, as they do not, to my mind, express clearly the nature of the structure they are intended to designate. The term, "lobular passages," is scarcely applicable to well defined, although somewhat irregular tubes, having an orifice of communication with a bronchial ramification, and a distinct, more or less rounded, extremity. Nor is that of "intercellular passages" less open to objection; it would seem to me to imply that the structure of the lungs was of a cellular character, and that throughout the network formed by it, open spaces existed in all directions,—a term which would be very applicable if we entertained the view propounded by Helvetius of the intimate structure of the lungs, but is little so to that now entertained. Again, the term made use of by Rossignol, although it expresses tolerably well the shape and arrangement of the tubes, yet is wanting in appropriateness, and is scarcely sufficiently specific; the "infundibulums," or "funnels" of the lungs, is a term which requires explanation, and does not in any wise convey to the mind the meaning it is intended to do. The expression adopted by Addison, "intralobular bronchial ramifications," is less open to objection than any of the previous ones, but does not make sufficient distinction between the bronchial tubes themselves, the convective channels, and those parts in which the function of respiration is performed. Moreover, the term would seem rather to imply that, immediately the air-tube entered the lobule, it terminated in these ramifications, which is by no means the case; for the bronchial tube of a lobule, in passing through it, gives off numerous branches, which themselves give off others, before they terminate in these "intralobular bronchial ramifications." This term therefore is, I think, objectionable, inasmuch as it appears to me to infer that all the tubes within a lobule are destined for the special function of the organ, and are none of them intended as convective channels.

The designation of Moleschott, "Malpighian vesicles," is an old term revived, and a very proper tribute to the genius of him who first led the way in the investigation of the intimate structure of the lung, but inasmuch as the parts implied have no real vesicular character, the term can scarcely be admitted into general use.

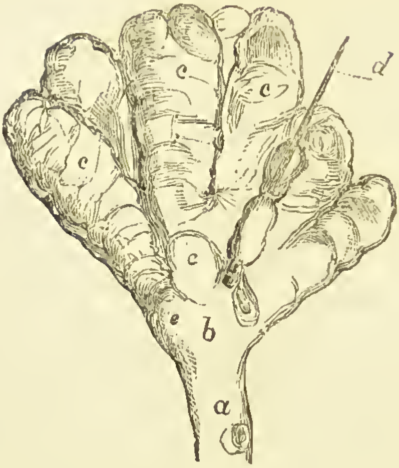
The latest investigator of these structures, Mandl, has adopted a term to which I think there is less objection than to any other which has been made use of, "terminal cavities;" but still this expression appears to me not to possess a sufficiently definite meaning. If we say "terminal cavities," it may fairly be asked, of what? of the bronchial tubes? We might as well say "ultimate ramifications," or "ultimate branches," and especially as the word cavity gives no clue either to the shape or character of the structure it is intended to designate.

Unwilling as I am to introduce a new term, where so many have been already adopted, I shall venture to do so, if for no other reason than its simplicity, and inasmuch as I believe it will express, in a shorter and more exact manner than any term previously used, the particular character and arrangement of the portion of the lungs under consideration. The term I propose to use is that of *air-sacs;* my reasons for employing the term I shall give after I have described the parts themselves.

The *air-sacs* are those tubes in which the bronchial ramifications end; they are situated at the surface, and throughout all parts of the lung; they are supported externally by the pleura, and within the lung they in part rest by their extremities, or their sides, against the bronchial tubes, and the branches of the blood-vessels, and through the transparent coats of the smaller bronchial tubes they are visible, as through the pleura.

The *air-sacs* consist of somewhat elongated cavities, which communicate with a bronchial ramification by a circular opening, which is usually smaller than the cavity to which it leads, and has sometimes the appearance of a circular hole in a diaphragm, or as if it had been punched out of a membrane which had closed the entrance to the sac; when this is the case, the sac dilates suddenly beyond the orifice.

FIG 14.[*]

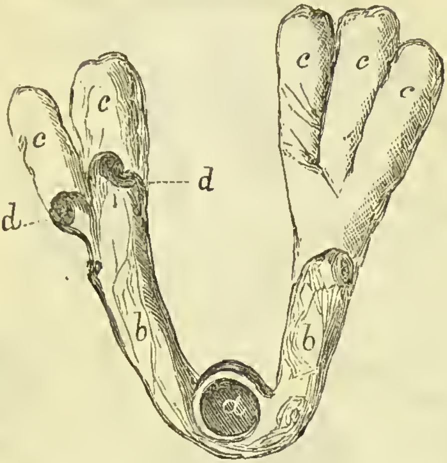


The sacs are arranged in groups; they are placed side by side, and are separated from each other by thin membranous walls; their shape, when properly inflated, or when distended by some material which has set in the sacs, such as gelatine, or a mixture of wax and turpentine, is polygonal; they approach very nearly to the circular form, but in consequence of their mutual pressure, their parietes become somewhat flattened. The sacs increase somewhat in size as they pass from the bronchial tube to their fundus,

---

[*] Fig. 14 is a drawing of a terminal bronchial tube, with a group of air-sacs, or lobulette, connected with it (human). *a.*, the terminal bronchial tube; *b.*, the dilated extremity of the terminal bronchial tube; *c. c. c.*, individual air sacs. At *d.* a bristle is seen passed into an air-sac; one end is seen opening into the common cavity in which the bronchial tube terminates. At *e. e.* are seen the openings of other sacs which lie beneath those which are exposed; six sacs are seen converging to the common centre. The markings in the air-sacs denote the boundaries of the alveoli. (Original.)

FIG. 15.*



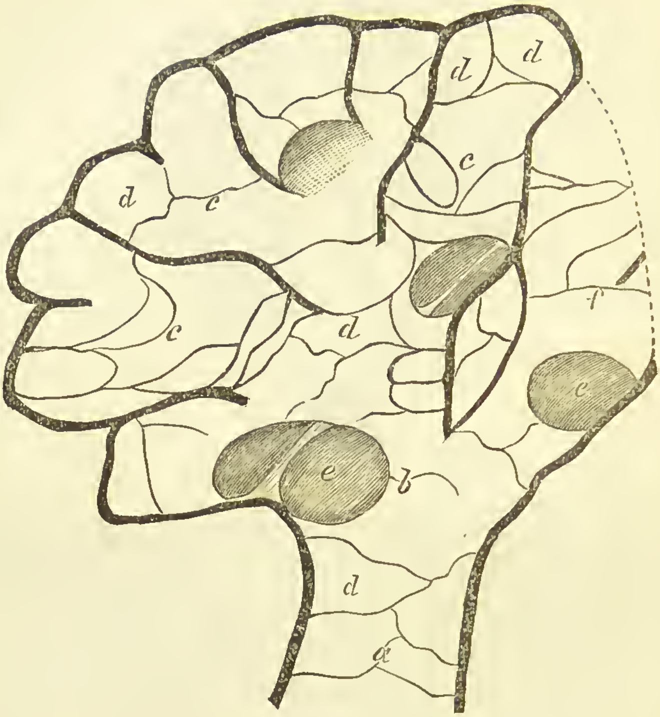
the latter being usually the broadest part of the sac; but they are often found to have an almost uniform diameter throughout. (See Figs. 14, 15, 16, 17.)

All the sacs pass from the extremity of the bronchial tube *towards* the circumference of the lobule in which they are placed; they consequently radiate from the tip of each terminal bronchial twig. The sacs connected with one bronchial termination do not communicate with those of another; each set of air-sacs is therefore a little lobule, or *lobulette*, which, in fact, represents the entire arrangement of the lung, and is a lung in miniature. As the air-sacs pass

---

* Fig. 15 is a drawing of two terminal bronchial tubes, with two groups of air-sacs or lobulettes. The terminal tubes are seen to pass from a bronchial tube (*a*), and they terminate each in a group of air-sacs. *b.*, terminal bronchial tube; *c. c. c.*, air-sacs; *d. d.*, openings leading to air-sacs beneath those exposed. This diagram was taken from the lung of an infant under one year of age. (Original.)

Fig. 16.*

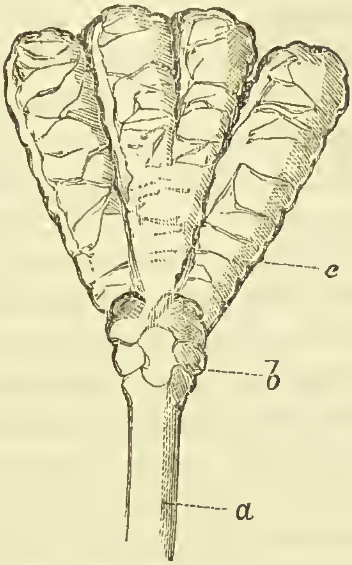


towards the boundary of the *lobulette*, they often bifurcate, and here and there circular orifices exist, which lead to smaller air-sacs, sometimes only to a small group of air-cells or *alveoli*, so small as scarcely to be considered as a sac. If we trace the sacs from

---

* Fig. 16. Ultimate bronchial tube, with air-sacs connected with it (of a cat). *a.*, ultimate brouchial tube; *b.*, dilated extremity of ultimate bronchial tube, forming the *point de réunion* of all the air-sacs; *c. c. c.*, the air-sacs; *d. d.*, the alveoli; *e. e.*, openings leading to other sacs. At *f.* a part of the wall separating two other air-sacs is seen, the whole of which sacs could not be included in the sketch. The drawing was made from the image reflected by means of the camera lucida. (Original.)

FIG. 17.*



their fundus we may say that, passing from the periphery of the lobulette, and diminishing somewhat in size, they all terminate in the dilated extremity of the bronchial tube. The sacs, as they pass in this manner, often join, two and three together, and these terminate in a single mouth; when this union of sacs takes place, there is apparently a gradual thinning of that part of the wall which lies between those thus joining. The tube which results from the union of two sacs has a smaller capacity than that of the two sacs taken together, but a larger capacity than either of them individually. (See Figs. 14, 16, 17.)

---

* Fig. 17. Theoretical view of the ultimate pulmonary tissue —viz., terminal bronchial tube, its dilated extremity, and its group of air-sacs or lobulette — divided transversely. *a.*, terminal bronchial tube; *b.*, cavity in which the air-sacs end; *c. c.*, the air-sacs (the central one is seen to divide). The markings denote the alveoli of the air-sacs, and of the dilated extremity of the bronchial tube.

The walls of which the air-sacs are composed are exceedingly thin and much sacculated, *i.e.*, they have in them a number of small, shallow, cup-like depressions, separated from each other by portions of membrane, which are more or less raised, and project into the interior of the sac. These are the parietal *alveoli* of some authors. The bottom of the air-sacs presents the same appearance as their lateral walls; in fact, the fundus is but the closed continuation of these walls, and the cup-like depressions or alveoli are here very numerous. These are the terminal alveoli of some authors; their number varies very much; I have counted as many as ten at the fundus of an air-sac in a cat's lung; in the human lung I have counted five and six, but the number is not usually quite so great. Close to the bottom of some of these sacs, in the human lung, a circular opening, similar to those already alluded to as leading to other sacs, small, constricted, is often seen, and has the appearance as if it led to another sac; on examination, however, it will be found to be simply produced by a projection inwards of the membrane of the sac, and to lead to a small cavity. (See Figs. 11 to 17.)

The number of *alveoli* existing in the air-sacs varies; in some they are very numerous, in others less so, but in all they are found. Rossignol states that each air-sac (infundibulum) contains from ten to twenty alveoli. My own observations entirely accord with this statement. I have found the number varying from eight to twenty. The sacs, by their fundus, rest, as I have said, on the pleura externally, but within the substance of the lungs they in part rest on, and are supported by, the bronchial tubes and blood-vessels. It is the alveoli and the air-sacs, with their partitions, which give rise to the appearances beneath the pleura, and in the smaller bronchial tubes described in pages 113 and 123.

The air-sacs are sometimes seen in the dried preparation to be curved or sinuous in their course; and occasionally they run for some distance nearly parallel with the pleura; this latter circumstance gives rise to an appearance in the lung injected with mercury, which I shall allude to hereafter. The air-sacs are separated from each other by thin walls, the membrane composing which, when the lungs are inflated and dried, is very transparent. The projection of this membrane, in the shape of thin processes having a sharp margin, constitutes the septa between the alveoli; and wherever an opening exists, leading into a smaller sac, this membrane projects in a similar way, and forms a circular orifice, which is much smaller than the sac to which it leads; the sac, in fact, dilates abruptly on the distal side of the opening. It is in the membrane composing these walls, and the septa of the alveoli, that the capillaries of the pulmonary artery are spread out.

I have used the term "*alveoli*" in speaking of the depressions in the walls of the air-sacs. This word was first used by Rossignol, and it seems to be admirably adapted to express the actual condition of the parts, which have been variously known under the names of "pulmonary vesicles," "air-cells," "capsules" (Lereboullet), &c.

A pulmonary *alveolus* is that portion of an air-sac which exists on the wall of the sac, and is circumscribed by a slightly raised margin, consisting of thin membrane. In shape it is more or less polygonal. The alveoli, as before mentioned, are found throughout the circumference of the sacs, and at their fundus. They are further found at the termination of the bronchial tubes.

It seems scarcely necessary to say anything in support of the word which I have adopted to express the peculiar structure situated in the air-sacs, as it has been already used by several authors; but as we are all so familiar with the terms "air-vesicle" and "air-cell," it may perhaps be worth while to consider whether the word *alveolus* is more appropriate than either of these expressions.

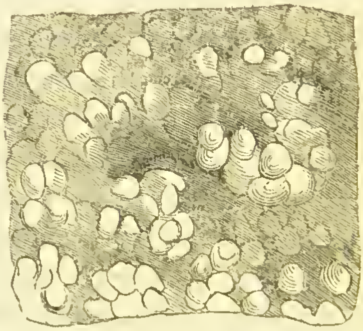
The term "air-vesicle," strictly speaking, means "air-bubble," and may exist without being enclosed within membranous walls; in fact, in any viscid fluid air-vesicles may be seen in abundance. The term has crept into use, I believe, under a misapprehension of the nature of the part it was intended to designate. So long as it was thought that the terminal bronchial tube gave off a number of little bladder-like processes, the word "vesicle" was not inappropriate; but now that, if we use the term, we intend it to designate a cup-like depression situated on the walls of a tube, its appropriateness becomes lost. The expression "air-cell" is open to this objection, that it implies a cavity enclosed by walls, and is therefore scarcely applicable to a depression or fossa. If we use the term *air-sacs* to designate the ultimate air-tubes, and *air-cells* to designate the depressions in their walls, there will be a danger of the two names being confounded, and the expressions misapplied; but by using another word to express the last mentioned parts this danger is obviated. The term "*alveolus*," or "*hole*," or "*socket*," already used in anatomy, appears to me well adapted to convey the meaning intended, has the advantage of not being new, and is not likely to be confounded with the term air-sac.

Some authors, as I have already mentioned, have described *parietal* and *terminal* alveoli. Rossignol makes a distinction between those situated on the sides of the bronchial tubes and "infundibulums" and those placed at the fundus of the "infundibulums;" the former he calls *parietal*, the latter *terminal.* Schultz, on the contrary, calls all those in the "infundibulums" *terminal*, and those in the bronchial tubes *parietal*. I have thought it undesirable to insist on this distinction, for as the alveoli are all continuous with one another, and similar in their arrangement, except so far as I have described, it seems to me better that they should be spoken of in connection with the locality to which they belong, than as *parietal* or *terminal.*

I have mentioned that the air-sacs are arranged in groups; the number of sacs which constituted a single group, viz., of those which communicate with an extreme bronchial tube, varies. I have counted as many as six communicating with a bronchial tube which had been incised horizontally, so that probably only half the sacs were left; this, however, is a larger number than is usually found; from six to eight or ten is the more common number. The groups are distinct from each other, and are separated by walls, which, however, seem not to be thicker than, nor to differ in any way from, the walls of the air-sacs, and in an adult inflated and dried lung it is not without careful observation that these partitions can be made out; but that such boundaries, to each set or group of air-sacs, or each *lobulette*, do exist, is plainly shewn by opening a bronchial tube in a recent lung, and following it to its ultimate division (which may be done with the aid of a dissecting microscope), when, by placing a fine blow-pipe at the opening leading to a set of air-sacs, and blowing through it, it will be seen that only a single group will be distended, thus proving that it is isolated from the groups which surround it.

The separation of the groups, or *lobulettes*, as I propose to call them, is further very distinctly seen in the lungs of infants. In the recent inflated lung of a young child, the line of demarcation between the different lobulettes

FIG. 18.*



---

* Fig. 18 is a drawing of a small portion of the surface of the lung of an infant, which had collapsed slightly after being removed from the body. It shows the groups of air-sacs, and the separation between them. (Original.)

is often very plainly seen beneath the surface of the pleura; it may be also seen in the fœtal lung artificially inflated, a fact I shall allude to again in speaking of the anatomy of the fœtal lung. (See Fig. 18.)

The shape of these groups of air-sacs or lobulettes is more or less pyriform, the apex being situated at the termination of the bronchial tube; the base, somewhat flattened, especially at the superficies of the lung, at the distal extremity of the sacs. (See Figs. 14, 15, 16, 17.)

A most excellent way of examining the air-sacs, and one which demonstrates most satisfactorily the manner in which those at the surface of the lungs are arranged with reference to the bronchial tubes, is the following:

A thin slice should be cut off the surface of a portion of lung which has been injected, inflated, and dried, and the portion itself (not the slice) should then be placed under the dissecting microscope. The cut orifices of the air-sacs will be observed. Very fine bristles should then be inserted into these tubes, the largest one being first chosen. It will be found that several of the bristles, passed into different openings, converge to a point a short distance from the surface of the lung. It will be known that they pass to a common point, as, by moving one of the bristles gently, it will act upon the others. Having placed bristles in all the air-sacs which converge to this spot, the bristles should be left in their position, and the bronchial tube should be laid bare on its proximal side, down to its termination, *i. e.*, the lung substance covering it should be removed, care being taken to stop just before reaching the spot where it communicates with the air-sacs. The number of bristles communicating with the spot thus exposed, will show the number of air-sacs belonging to one group. The termination of the bronchial tube will be seen to be somewhat expanded, and the air-sacs will be found, many of them, to communicate with it by a circular orifice, which is smaller than the sac itself. This orifice has very much the appearance as if it had been punched out of a membranous wall which had been stretched across the opening; it exists in the centre of the membrane which projects inwards towards the middle of the cavity.

When the bronchial tube has been exposed in the way I have mentioned, and the mode of communication with the air-sacs observed, a section may be made longitudinally through one or more of the latter; it will be then seen that the sacs lie side by side, and that they occasionally give off smaller sacs; the manner also in which they divide, and the mode in which they terminate, will be observed. It will also be seen, that as each bronchial tube approaches its termination, it has here and there, throughout its circumference, small circular orifices, which are the commencements of small canals, leading to groups of air-sacs or lobulettes; and it will further be seen that the tube itself, at its termination, has a number of alveoli in its walls.

Another very excellent way of examining the terminal bronchial tubes, and the commencement of the air-sacs, is to soak a piece of lung that has been injected, inflated, and dried, in spirit for some time, and, when the piece is well saturated, to dissect it under the microscope. By imbibition of the spirit the mass of lung swells, and the air-tubes and sacs remaining distended, the parts assume nearly the size and shape they have in life. When such a piece is examined, very frequently, on opening the bronchial tubes and following them to their end, their *alveoli* may be plainly seen, as well as the orifices leading to the air-sacs, and the band of elastic fibres which surrounds the opening into each sac becomes apparent.

Many observers who have investigated the nature of the lungs have contented themselves, for the most part, with the examination of sections of the lungs, a mode of examination which must necessarily give a very imperfect notion of the arrangement of their tissue. The ultimate air-tubes are not so small but that they may be recognised by a good lens, and, under a magnifying power of ten to twenty diameters, they can be followed to their termination, provided their walls are *opaque* and *resisting*, conditions which may be brought about by the mode of preparation I have adopted.

If we examine the cut surface of the interior of the lung which has been injected, inflated, and dried, or a thin slice from the interior, we always observe, in the former, a number of cavities, which present different appearances at different parts; some, we find, are elongated, and have the appearance of gutters, with a number of depressions in them; again, others are less elongated, and more or less circular; and again, we may observe a large, circular, clearly defined orifice of a divided bronchial tube. A thin slice will present us with a number of foramina of different sizes and shapes, resembling those previously described, except that, in such a slice, a divided bronchial tube may appear. In whatever part we incise the lung, and in whatever direction, we find the same appearances. This results from the fact, that the section is almost sure to include air-sacs belonging to different lobulettes, which therefore pass in different directions, and that it divides them, some transversely, others with varying degrees of obliquity.

Do the Air-sacs communicate with each other? — It becomes a very important question, in connection with the anatomy of the air-sacs, whether they have any orifices of communication with each other, independently of that by which they communicate with the bronchial tube. Different opinions have been expressed on this point; on the one hand, Adriani has stated. that he has observed orifices in the sacs, by means of which they communicate with each other, and he specially mentions that they are most clearly to be observed in the lung of the stag. He describes them as very small, and he gives their dimensions.* Dr. Williams also considers that the "intercellular passages" intercommunicate, and are perforated by secondary passages at every point.† On the other hand, we have the statement of Rossignol, who described more accurately than those who preceded him, the arrangement of the ultimate air-tubes, that no such communication exists between the "infundibulums," and the opinion he has expressed has been confirmed by the observations of Schultz,* Mandl,† and Milne Edwards.‡

---

* *Adriani. Op. cit.*, page 41.

† *Dr. Williams. Encyc. Anat. and Phys., Art. Lungs.*

From observations made with much care, and frequently repeated, I have satisfied myself that the opinion of Rossignol is correct, and that, as far as the lungs I have examined are concerned, Adriani and Williams have erred with respect to the intercommunication of which they have written. I have never found, either in the lungs of man, or of the dog, or cat, or pig, or sheep, or of any other mammal I have examined, any lateral orifices of communication between the different sacs of each lobulette. Frequently an opening will be found in a sac, circular in outline, and appearing as if it led to another sac lying by the side of the first; but careful examination, and dissection under the microscope, have always proved that such openings have led to small sacs, or offsets of the tube in which they were situated, and did not constitute lateral means of communication with other sacs. I may express my opinion, that the air-sacs do not communicate with each other, except through the medium of the dilated extremity of the bronchial tube in which they all end, and that the only opening they have in them, unless such an offset exist as I have described, is that by which they thus terminate. I believe that Adriani has been misled by supposing that the openings I have alluded to, as leading to offsets from a sac, really constituted lateral means of communication from "infundibulum" to "infundibulum"; and it appears to me that Williams has fallen into a similar error. When I made my first observations, I came to the same conclusions as these authors had done; and it was not till I had followed out, by dissection under the microscope, several of these openings, and had passed bristles into the adjoining air-sacs, that I convinced myself of my mistake.

---

* *Schultz. Op. cit.*

† *Mandl. Op. cit.*

‡ *Milne Edwards. Op. cit.*

Independently of the fact that direct observation has convinced me that lateral communications do not exist, it seems to me that such an arrangement would somewhat interfere with the exit of the air from the air-sacs. It is important that the air should pass readily to and from the fundus of each sac, but if lateral openings existed, its transit would be interfered with, especially if such transverse "intercellular passages" as have been depicted by Dr. Williams were found.

In the description I have given of the appearances presented by the air-sacs, I have more especially described those which are situated at the surface of the lung. My observations have not simply been confined to these; on the contrary, I have examined the sacs in every part of the organ, and invariably with the same result, and I venture to think that the description I have given will be found universally applicable. Of the various lower animals I have examined, the cat, the dog, and the pig afford great facilities for ascertaining the arrangements of the air-sacs, especially the first of these animals, in which the sacs are larger than in any other animal I have examined. The chief distinctions I have observed between the air-sacs of man and those of the cat are that the former are more elongated than the latter, and that they have fewer openings in them leading to other smaller sacs.

It will be seen from the description I have given of the pulmonary lobulette and its constituent air-sacs, that a remarkable resemblance exists between it and the "pulmonary sac" of the higher batrachian reptiles. In the latter the air-tube ceases suddenly in a circular orifice, and the pulmonary sac is developed beyond it. This consists of a simple sac in which a number of secondary cavities are formed by the projection of the internal membrane into the interior of the sac. These cavities or "sacculi" are of a polygonal shape; their base rests on the outer wall of the pulmonary sac; their mouth opens towards the long axis of the cavity: they are not plane and simple cavities, but have a number of depressions or secondary chambers, or "alveoli," within them, which are separated from each other by membranous septa, and resemble those of the air-sacs of the human lung. Each of these "sacculi" may be fairly considered as the representative of an "air-sac" or "infundibulum" of the mammalian lung; and as a number of these open into the dilated extremity of the air-tube, the whole pulmonary sac comes to resemble very closely the *lobulette* of the lung, the sacs of which all open into the terminal dilatation of the bronchial tube. But another view may be taken of the constituent parts of the *lobulette*. Each air-sac may be not unfairly considered as representing the entire batrachian lung. It commences in a circular orifice, possesses a number of secondary cavities, is independent of those sacs by the side of which it lies, and opens into the termination of a bronchial tube. In whichever way we choose, therefore, to view the mammalian lung, we still find it conformable to the type of that of the batrachian reptile.

It was from a knowledge of the simple character of the terminal air tubes, their peculiar shape — nearly circular and somewhat elongated—their usually broad fundus, and rounded orifice, that I conceived the term "air-sacs" would be specially applicable to them. I consider it desirable that the structure should be known by some distinctive name; and although there are objections which it might be easy to advance against any term that was used, it appears to me that the one I have chosen is less open to objection than any I have been able to think of.

STRUCTURE OF THE AIR-SACS AND ALVEOLI.— The air-sacs being the continuation of the bronchial tubes, it becomes important to ascertain how far the structures which exist in the latter are present in the former, or how far they become modified. Each air-sac is surrounded by its wall, which isolates it from others, and each alveolus has its septum, which is derived from the wall of the air-sac, and which partly separates it from the surrounding ones.

Elastic Tissue. The walls of the air-sacs consist in large proportion of yellow elastic tissue, the fibres of which are arranged in bundles, or singly;

a bundle of these fibres is found surrounding the mouths of the sacs, and the examination of a small portion of lung simply including the walls of the sacs, demonstrates the existence of numerous elastic fibres, encircling the margins of the alveoli, and running through the walls in different directions. The last mentioned fibres are not placed close together, but considerable spaces are left between them. The partitions separating the alveoli from one another always contain some of these fibres. At the circumference of the alveoli and around the openings of the sacs the fibres are often gathered into bundles of considerable size, and they have an arched or circular arrangement; they may frequently be seen passing from the wall of one sac to that of another, or from the septum of one alveolus to that of another.

The elastic fibres of the air-sacs are placed immediately beneath the basement membrane which lines the sacs, and as they do not form an uniformly complete coat, but are placed at intervals leaving spaces between them, they cover but little of the blood-vessels, and thus they do not interfere with the action of the air on the blood.

The elastic fibres form a very important element in the air-sacs; they constitute in great measure the strength and support of the walls, and by their circular arrangement around openings and in the septa of the alveoli, they tend to preserve the form of those parts and keep them patent, so that if the circular orifice leading into an air-sac be compressed, the original shape is restored as soon as the pressure is remitted. I need not dwell on the physiological importance of this structural arrangement.

Basement Membrane. — In addition to the elastic fibres just described, the air-sacs are lined with a membrane, homogeneous and transparent, which has been considered as a basement membrane, in fact a prolongation of that which lines the bronchial tubes. In speaking of this membrane Bowman says, "In the air-cells the basement membrane assumes a most interesting and remarkable development, for it constitutes almost the entire thickness of their walls, the epithelium being of extreme delicacy. It seems to be here strengthened by interlacing arches of elastic fibrous tissue, but to be itself transparent and homogeneous, as elsewhere."*

In the walls of the air-sacs two layers of this basement membrane must exist, one on either side, having between them the plexus of blood-vessels with the yellow elastic tissue. It is a prolongation of that which lines the bronchial tubes, and at the commencement of the bronchial alveoli it assumes a peculiar aspect. The mucous membrane has somewhat the appearance as if it terminated in an abrupt margin, and this no doubt led Mr. Rainey to suppose that it was not prolonged into the air-sacs; † but a careful examination will show that it does not cease at this spot, but is continued on as a very fine, delicate, and transparent membrane over the vessels of the pulmonary plexus. This arrangement may be seen in an injected preparation. Every examination I have made, whether of the uninjected or injected lung, has demonstrated the existence of a homogeneous, transparent membrane, supported by the capillaries and the elastic tissue, as a constituent part of the air-sacs.

---

* *Cyc. Anat. and Physiol., Art. Mucous Membranes.*

† In speaking of the bronchial tubes, Mr. Rainey says, "Having arrived within about one-eighth of an inch of its surface (the surface of the lung), the membrane also terminates, but somewhat abruptly, after which the passages . . . . continue in the same direction as the bronchial tubes, but without having any perceptible membranous lining." — *Med. Chir. Trans.*, vol. xxviii., 1845.

Epithelium.—Most observers now admit that the membrane lining the "air-cells" is covered by an epithelium, but as some doubt has been thrown upon this fact, and especially by the statements of Mr. Rainey, whose opinion is entitled to great respect, I think it desirable, before I give the results of my own observations, to state briefly the opinions that have been expressed by those who have paid particular attention to the subject.

Dr. Thomas Addison was the first to surmise, from the difference between the phenomena of pneumonia and bronchitis, that the air-cells must be destitute of epithelium.

Mr. Rainey has denied the existence of an epithelium on the lining membrane of the air-cells. In a paper on the anatomy of the lung of the bird, he says, "Neither does the ciliated epithelium lining the bronchial tubes extend into the intercellular passages, and from thence into the air-cells, or rather air-spaces, but it ceases where the bronchial membrane terminates. In the mammal, but especially in man, in whom the air-cells are very large, the fact of their having no epithelial lining can only be proved by a careful examination of the parts with the microscope, and therefore, with no other means than those of deciding this question, it might always remain *sub-judice*, so long as persons are found who are more ready to confide in the assertions of others, than submit to the pains and difficulty of examining the point for themselves."* In an article subsequently written by Mr. Rainey, the whole subject is reviewed, and the opinions expressed by other observers considered, at some length. Mr. Rainey attempts to disprove the arguments adduced in favour of the existence of an epithelium, and to account for the appearance which is seen in connection with the lining of the air-cells, on the ground that it results from the existence of nuclei in the walls of the capillary blood-vessels, together with the retiform arrangement of those vessels and the sharp threads of the elastic tissue.†

The opinion entertained by Mr. Rainey, as to the absence of an epithelium, is also that expressed by Messrs. Todd and Bowman, in their Physiological Anatomy,‡ although the latter author admits the presence of an epithelium in the air-cells, in his article on "Mucous Membranes" (see quotation above).

On the other hand, the following authors may be quoted as entertaining an opinion that the air-cells are covered with an epithelial lining:—Carpenter, in his Human Physiology, page 513, fourth edition, says, "The walls of the air-vesicles are formed of a very thin and transparent membrane . . . . which is lined by an epithelial layer composed of minute polygonal cells, of from $\frac{1}{1600}$ to $\frac{1}{2250}$ of an inch in diameter, and $\frac{1}{2800}$ to $\frac{1}{3800}$ in thickness." (The measurements he gives are Kölliker's.)

---

* *Med. Chirurg. Trans.*, vol. xxxii., 1849, p. 51.

† *Brit. and For. Med. Chir. Review*, No. xxxii. p. 491.

‡ *Physiological Anatomy*, chap. xxix.

Quain and Sharpey state, "The membrane of the air-cells is covered by a stratum of squamous epithelium."

Kölliker says, "The epithelium of the air-cells is of the common tessellated kind, without cilia, and composed of polygonal, pale, granular cells, in morbid states containing fat."

Rossignol admits the presence of a pavement epithelium on the walls of the alveoli; he says, "Au moment ou apparaisent les alveoles parietales, l' epithelium qui jusqu' alors avait été vibratile, devient pavimenteux."*

Adriani, in his essay, gives us the opinion of Schroeder Van der Kolk, as well as his own, with reference to the presence of an epithelium. He says that the mucous membrane of the alveoli is covered by a pavement epithelium, in which nuclei may be seen by the aid of acetic acid: the following are his words — "Alveoli constant membrana subtilissima structura carente, quæ autem membrana mucosa tegitur epithelio pavimentoso (plaat epithelium) admodum pellucido, in quo potissimum ope acidi acetici nuclei conspiciuntur."†

---

* *Op. cit*, p. 68.

† *Op. cit.*, p. 61.

Schultz believes in the existence of a pavement epithelium.*

Williams states that he has, from many special examinations, convinced himself of the existence of the epithelium, which he proposes to call *hyaline epithelium.*†

Dr. Radclyffe Hall, in an article on the development of tubercle, admits the presence of an epithelium in the air-cells, and has given a sketch of it as he has found it in health. He says, "The outlines (of the epithelia) are less sharply defined than in most other varieties of pavement epithelium; but the flat cells are bounded by a dim line of limitation. In appearance they are thin, almost transparent, and have a slightly nebulous and somewhat ill-defined nucleus."‡

Mandl, whose recent enquiries into the microscopical anatomy of the lungs are worthy of attention, is of opinion that the pulmonary air-sacs are lined by granules of extreme smallness, resembling the nucleus of newly formed epithelial cells arrested in their development.§

Milne Edwards agrees with the opinion expressed by Mandl.||

From careful and repeated examination of a very considerable number of specimens of the lungs of man, and various mammals, I have perfectly satisfied

---

* *Op. cit.*

† *Cyc. Anat. et Physiol., Art. Lungs.*

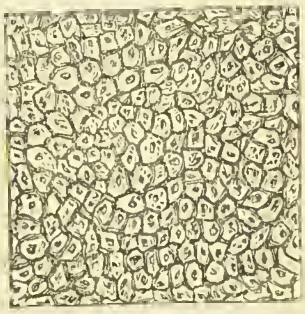
‡ *Brit. and For. Med. Chir. Review*, No. xxx., p. 481.

§ *Anat. Micros.*, vol. ii., p. 327.

|| *Leçons sur la Physiologie, etc.*, vol. ii., p. 326.

myself of the existence of an epithelium in connection with the walls of the air-sacs. No doubt whatever can be entertained, that the ciliated columnar epithelium, so characteristic of the bronchial mucous membrane, ceases at the commencement of the alveoli, the true respiratory portion of the lungs; for in no instance, in which proper precautions have been taken to avoid errors, have I seen an epithelium of such a character present in the air-sacs. It seems to me altogether unnecessary to attempt to prove, from analogy, that an epithelium *ought* to be absent or present in the true pulmonary system, for if the fact be capable of demonstration, no theoretical argument against it can ever avail, and none in proof of it is required.

Fig. 19.*



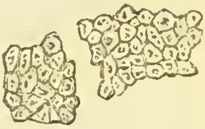
If a piece of the fresh lung of any mammal be taken, the pleura carefully stripped from it, and a small portion of the "ultimate pulmonary tissue" be removed and washed, and then placed under the microscope, an appearance will be observed not very unlike that which is presented by the free surface of a serous membrane. The portion of tissue examined will be found covered with a number of small flattened bodies, of various sizes and shapes, many of them approaching the circular, but most of them polygonal; beneath these bodies, in different parts, will be seen bands of yellow elastic fibres and capillary blood-vessels. The flattened bodies are tolerably distinct, but the outline of many of them is faint; nuclei are apparent in a large number of them. (Fig. 19.)

---

* Fig. 19 shews the appearance of the epithelial cells lining the air-sacs, highly magnified, and treated with acetic acid. Some of the centre cells were drawn with the aid of the camera lucida, their outline being traced as thrown down on the paper.

Round the sides of the piece of tissue under examination a number of detached bodies, and also small granules, will be seen, resembling those just described. If now acetic acid be added, the outline of these bodies becomes more distinct, and the nuclei more apparent. These bodies have all the characteristics and appearances of epithelial cells, and such they seem to me to be. They have not quite the same appearance as those of a serous membrane; they are smaller, and more rounded in shape, and less distinct in outline, but in the possession of nuclei (which are visible in all after the addition of acetic acid) and granular matter, they resemble the ordinary pavement epithelia. (Fig. 20.)

FIG. 20.*



The cells form a distinct and complete coating to the walls of the air-sacs and alveoli, and they rest immediately upon the basement membrane. My measurements have given from $\frac{1}{3000}$ to $\frac{1}{5000}$ of an inch as the diameter of these cells. In the cat, I have found them varying from $\frac{1}{2000}$ to $\frac{1}{5000}$ of an inch; in the sheep, from $\frac{1}{3750}$ to $\frac{1}{5000}$ of an inch.

---

* Fig. 20. Epithelial cells lining the air-passages of the pigeon, highly magnified. Drawn with the aid of the camera lucida.

Although, as I have previously stated, demonstration is better than analogy, yet, with reference to the existence of any particular structure of the human body, it becomes of the utmost importance to ascertain how the parts which have a similar function to perform in other animals are constituted; and especially does this apply where investigation can only be carried on by means of the microscope. I have frequently observed a pavement epithelium present in the lungs of reptiles, and Dr. Williams has stated that throughout the whole range of the animal kingdom, he has found that an epithelial covering exists on the surface of the true respiratory tissue. "In no instance whatever," he says, "either in the vertebrate or invertebrate kingdom, has it been found in the present extended inquiry that the vessels of a real breathing organ can exist under a perfectly 'naked form.'" "The gills of fishes are furnished with a very marked epithelial covering. The temporary branchiæ of the amphibia are clothed with an epithelial lining, the cells of which admit of ready and conclusive demonstration"; and with reference to birds, he says, "The apparently naked vessels of the air-cells are really invested by a hyaline epithelium."*

I can confirm the observations which Dr. Williams has made with respect to the lungs of birds and the gills of fishes. The existence of an epithelium in the air-passages of the bird seems to me to be so obvious and apparent, as not to leave the slightest doubt of the fact. Under a magnifying power of 360 I have seen the cells perfectly distinctly. They are very small, and present at first a very faint outline, but, on the addition of acetic acid, their outline comes clearly into view, and their nucleus is rendered very apparent. On the gills of fishes an epithelium of a similar character is also easily recognised.

---

* *Cyc. Anat. and Phys. Art. Lungs.*

In examining these epithelia, a perfectly fresh lung should be used, for they seem soon to become destroyed, or at least to lose their characteristic appearance. In a lung which is not fresh, they are less numerous and less distinct than in one that is so.

It forms no part of my intention to enter further into the controversy with respect to the existence of this epithelium, nor to attempt to reconcile the apparent discrepancies which exist in the accounts given of it by different observers. It appears to me very probable that some of those who have spoken of the indistinct and faint outline of the epithelial cells, have not taken the precaution to examine the structures with the aid of acetic acid, and hence has resulted the description given of them, as imperfect in outline and indistinct in character. The method I have adopted has been previously described; and that the appearance I have witnessed does not result from the arrangement of the capillary vessels and elastic tissue, with the persistent nuclei of the former, I am firmly persuaded.

DIMENSIONS OF THE ULTIMATE BRONCHIAL TUBES, AIR-SACS, AND ALVEOLI. — The following dimensions are given as the result of a series of observations, on preparations which represented as accurately, I believe, as possible, the lungs in their ordinary condition of health and normal distension.

In infants under one year, I have found that the *ultimate bronchial tube* varied in diameter from $\frac{1}{85}$ to $\frac{1}{100}$ and $\frac{1}{120}$ of an inch; the *terminal dilatation* of the tube, from $\frac{1}{50}$ to $\frac{1}{75}$ of an inch; the *air-sacs*, from $\frac{1}{80}$ to $\frac{1}{110}$, $\frac{1}{120}$, and $\frac{1}{150}$ of an inch; and the *alveoli*, from $\frac{1}{150}$ to $\frac{1}{170}$, $\frac{1}{200}$, $\frac{1}{300}$, and $\frac{1}{350}$ of an inch.

In adults, the *ultimate bronchial tube* varied from $\frac{1}{50}$ to $\frac{1}{60}$, and $\frac{1}{100}$ of an inch; the *terminal dilatation* of the tube, from $\frac{1}{35}$ to $\frac{1}{50}$ of an inch; the *air-sacs*, from $\frac{1}{45}$ to $\frac{1}{60}$ and $\frac{1}{85}$ of an inch; and the *alveoli*, from $\frac{1}{85}$ to $\frac{1}{100}$, $\frac{1}{120}$, $\frac{1}{150}$, and $\frac{1}{250}$ of an inch.

In a woman aged sixty-seven, whose lungs were healthy and normally distended, the air-sacs varied in diameter from $\frac{1}{45}$ to $\frac{1}{75}$ of an inch, and the alveoli from $\frac{1}{120}$ to $\frac{1}{200}$ of an inch.

I have found the length of the air-sacs to vary from $\frac{1}{15}$ to $\frac{1}{12}$ and $\frac{1}{10}$ of an inch in the adult; and in the infant under one year, from $\frac{1}{30}$ to $\frac{1}{25}$ of an inch.

It will be seen, by the table, that there is a marked difference in the size of the air-sacs in the infant and the adult; in fact, a progressive increase in their dimensions takes place until the lungs have reached their full size. It is easy to see why this should be. All the air-sacs are developed, as will be hereafter shewn, before birth; they exist at that time, in their full number, and ready to perform their function. No subsequent formation of air-vessels takes place, and consequently it is only by an increase in the dimensions of the bronchial tubes, and their ramifications, that their lungs can expand with the increasing capacity of the thorax. We thus see that, however large the lungs may become, they still have only the same number of air-tubes as they possessed at birth, and their enlargement must necessarily result from an increased capacity of these tubes. Magendie has remarked that the "air-cells" increase progressively with increasing age; my own observations do not entirely accord with this view; in the healthy lungs of aged individuals I have not found the air-sacs or alveoli possessing a greater capacity than those of full-grown adults; my observations, however, on this point are not yet sufficiently extensive to enable me to speak positively as to the truth or otherwise of Magendie's remark.

It has been said, that the "vesicles" of the lung are larger towards the surface than in the interior of the lung. This statement seems to me altogether devoid of proof. It is quite true that, in a lung which has been inflated and dried, those "vesicles" which are situated at the surface beneath the pleura, appear larger than those which are situated at a distance from it, and from the observation of this fact in all probability the statement has been made; but it must be borne in mind that this is the result of the collapse of the lung which takes place during desiccation. When a lung is inflated, and slowly dried, the surface is that which dries most quickly; and the *air-sacs* and *alveoli* there situated, being subjected to but little pressure, do not collapse to any very great extent, and thus they maintain a size approaching that they originally had; but with the interior of the lung the case is altogether different; the shrinking which necessarily takes place gives rise to considerable pressure on the air-sacs, and collapse of them results, producing an appearance of small "vesicles," from the process which is adopted, and not from any structural arrangement. From the examination of the human lung under various modes of preparation, and of the lungs of other animals, I have been led to the conclusion that there is no real difference of size between the superficial and deep air-sacs and alveoli of the lungs, nor yet between these structures in different parts of the organ; nor is it easy to see on what principle such a condition would be probable, or on what theory it could be expected.

MODES OF PREPARING SPECIMENS OF THE LUNGS FOR EXAMINATION.—In examining the arrangement of the ultimate air-tubes of the lungs, several modes of preparing the organs may be resorted to, and the observer should by no means confine himself to any one. Without some mode of preparation it is impossible to ascertain the exact disposition of the ultimate ramifications of the bronchial tubes, but, at the same time, it is quite possible to follow the tubes *as far* as the air-sacs, after a little practice; and some important points may be made out by a dissection under the microscope of a recent unprepared lung, or of one which has been preserved in spirit for some time.

The various methods of preparation hitherto adopted have been —

1. Inflation of the lung through a bronchus or bronchial tube, and subsequent desiccation.

2. Injection of the air-tubes with mercury, or some other substance, such as wax, &c.

3. Injection of the blood-vessels with some opaque material, and inflation of the air-tubes, with subsequent desiccation.

4. Injection of the blood-vessels, as in No. 3, and of the air-tubes, with a transparent substance, which becomes solid on cooling.

1. The first mode of preparation is the oldest and most simple; it enables us to follow easily the bronchial tubes to their termination, and to observe their arrangement and mode of division; but, arrived at this spot, difficulties present themselves for the observation of the air-sacs, which render a correct appreciation of these structures almost impossible. The extreme fineness of the tissue composing the sacs, and its great transparency, render it very difficult, I may say almost impossible, except to the practised hand, to trace out the arrangement of the sacs; and it is further very difficult to make out the alveoli, from the same causes. For the examination of the surface of the lung, in order to see the arrangement and shape of the terminal alveoli, a specimen prepared in this manner answers well, but for the investigation of the interior of the sacs it is of little use.

2. The method of injecting mercury into the lungs was employed by Willis, Reisseisen, and others; it consists in allowing the fluid to run into a

bronchial tube, and find its way into the air-sacs. This process can only show the form which the ultimate air-tubes assume at the surface of the lobules. When a lung prepared in this way is examined, the mercury is seen to present itself beneath the pleura in little roundish, or oblong, or oval globules, which have the appearance of each filling a tube; and this has given rise to the supposition that each bronchial tube terminated in a series of lateral *culs-de-sac.* The appearance presented results from a globule of mercury filling each alveolus, and from the septa between the alveoli partly separating the different portions of the fluid. The great weight of the mercury causes the globules to assume a rounded form, but this cannot be considered as indicative of the normal shape of the alveoli, but as the result of the specific gravity of the material filling them; and this constitutes a great objection to the employment of this method, even if we only want to examine the surface of the lung; but if we wish to penetrate into its interior, and examine the course of the smaller bronchial tubes, and the distribution of the air-sacs, the opacity of the substance and its fluidity preclude all attempts.

On examining a piece of lung prepared in this manner, it is easy to see how Reisseisen and others have erred in imagining that each bronchial tube terminated in a cul-de-sac. The mercury having the appearance of a large number of small half globules is exactly such as Reisseisen has so accurately described. This appearance, however, is deceptive, and results from the cause I have previously stated, as is at once discovered when a piece of lung, inflated and dried, or, far better, injected, inflated, and dried, is submitted to observation. The opacity of the mercury also prevents the sacculated condition of the walls of the air-sacs being seen, and renders impossible any accurate investigation of the smallest bronchial tubes.

The injection of wax, or material of a similar character, affords no facility for an investigation of the lung. When the substance reaches the air-sacs a solid mass is formed, from the examination of which no satisfactory result can be obtained, at least I have never been able to obtain any.

3. When I began to investigate the structure of the lungs, and before I had ascertained the various modes of preparation which had been previously resorted to, I first tried the methods just alluded to, viz., inflation and desiccation, and injection of mercury and wax, but deriving from them no satisfactory result, it occurred to me that if I could make the walls of the ultimate air-tubes opaque, and at the same time inflate and dry them, I should have the parts in a far more favourable condition for tracing out the tubes than by the adoption of any other means. I accordingly inflated a piece of lung, injected and dried it. I subsequently found that this method had been pursued by Rossignol originally, and afterwards by others. The plan I have adopted, and which I believe affords the best means for investigating the lung tissue, consists in the injection of a coloured solution of gelatine into the blood-vessels, inflation of the air-tubes, and gradual desiccation.

In my first attempt I inflated the air-tubes before I injected the blood-vessels, but I afterwards injected before I inflated. The colours I have used have been red, yellow, and blue. The red, a finely powdered vermilion; the yellow, a chromate of lead, formed at the time by the decomposition of acetate of lead by bichromate of potash; the blue, a Prussian blue, formed by the decomposition of ferrocyanide of potassium and sesquichloride of iron. When a piece of lung is well injected, the walls of the air-sacs become almost entirely opaque, their outline may be distinctly seen when they are divided, and, the vessels in the walls being filled with the dried gelatine and colouring matter, dissection under the microscope can be carried on with great facility, without which I believe it is impossible to form a definite notion of the anatomy of these parts. The injection used by Rossignol was a mixture of turpentine and copal varnish, coloured with finely powdered vermilion. I have tried this injection, but have been somewhat disappointed with it, and I much prefer that I have alluded to. Of the colouring matters I have found the yellow chromate of lead the best.

It may be said that there is danger, in inflating the lungs, of rupturing the walls of the air-sacs, and thus producing an abnormal appearance. The objection is more plausible than real; it is not necessary to inflate forcibly, although the lung should be fully distended, because considerable collapse takes place during desiccation; and further, the walls of the sacs are sufficiently strong to resist, without yielding, any reasonable amount of pressure.

It may be further objected that this process does not enable us to see the exact size of the air-sacs, nor yet their shape, in consequence of the collapse which takes place during desiccation. No doubt this is true to a certain extent; the sac shrinks, so that the size diminishes, but the shape does not necessarily alter, although the capacity does. However, in taking the dimensions of the sacs, we should make use of a specimen prepared by the method mentioned under the fourth head, or else of small portions of lung normally distended, and rapidly dried, so as to prevent collapse taking place. The rapid desiccation must not be effected by any artificial means; but if only a small piece of lung be distended, and exposed in the open air, its most superficial sacs soon become dried.

4. Under this head are included those processes of preparation of the lung substance, which, whilst the walls of the air-tubes are rendered opaque by injection of their blood-vessels, their cavities are at the same time filled with a material which is either transparent, or may be made so by some application. Such methods are the injection of the blood-vessels, as before described, and of the air-tubes, with a solution of gelatine, or a mixture of turpentine and wax.

With respect to the injection of gelatine, it usually happens, when that substance is used as a vehicle for injecting the blood-vessels with some opaque matter, that the colouring matter is left in the vessels, and a portion of the transparent gelatine exudes into the air-tubes; and this has appeared to me as good a way as any of effecting an injection of this kind.

When such a preparation is dried, and then soaked in spirit and water, it swells, and assumes much the shape it has in its normal condition, and much information may be derived from an examination of it.

When a piece of lung, in which the blood-vessels are injected, has injected into its air-tubes a mixture of turpentine and wax, and is left to dry, and then a slice of it is moistened with Canada balsam, as suggested in Adriani's thesis, the substance filling the air-tubes becomes transparent, and the outline of the air-sacs and ultimate bronchial tubes is well seen, and a very correct notion of their shape can be formed.

I have adopted both the above plans in my investigation of the ultimate pulmonary tissue, and have derived from them much information as to the exact shape of the air-sacs; but for ascertaining, in the first instance, the arrangement of these sacs, and their mode of communication with the bronchial tubes, I do not think that either of them is equal to that of injection and inflation, as before recommended.

VII. The Blood-vessels.

They consist of two sets — the Pulmonary Arteries and Veins; the Bronchial Arteries and Veins. The Pulmonary Artery: its Course and Relations; Dimensions — Right Pulmonary Artery: Dimensions — Left Pulmonary Artery: Dimensions — the Pulmonary Veins: the Right Veins; the Left Veins — the Pulmonary Arteries within the Lungs — Arrangement of the Capillaries in the Air-sacs and Alveoli — Size of the Capillaries, and of the meshes of the Capillary Plexuses, of the Air-sacs — the Pulmonary Veins within the Lungs — the Bronchial Vessels — the Arteries: their number, &c. — Distribution of the Bronchial Arteries and Veins, and their mode of communication with the pulmonary system of vessels — Observations of Rossignol; of Adriani; of Dr. Heale; of Dr. Williams; of Kölliker; of the Author — Course and Distribution of the Bronchial Arteries — Communication between the Bronchial and Pulmonary Vessels — the Bronchial Veins — Observations of Reisseisen.

The Blood-vessels of the lungs consist of two sets, which are derived from different sources, and are destined to perform functions of a different character.

First, are the vessels the object of which is to carry the blood for the special function of the lungs, and these are, — *a.* The Pulmonary Artery and its branches, which convey the venous blood from the right side of the heart to the air-sacs of the lungs; and *b.* The Pulmonary Veins, which convey the arterial blood from the air-sacs of the lungs to the left side of the heart.

Second, are the vessels destined for the nourishment of the bronchial tubes, the blood-vessels, and the areolar tissue of the lungs,—*c.* The Bronchial Vessels, viz., *α.* The Bronchial Arteries derived from the aorta, or one of its branches; and *β.* The Bronchial Veins.

a. THE PULMONARY ARTERY AND ITS BRANCHES.

The Pulmonary Artery, *vena arterialis* of the ancients, is the vessel which carries the venous blood from the right side of the heart to the lungs. It is a short wide vessel, taking its origin from the infundibulum, at the upper and anterior part of the right ventricle. It passes upwards, backwards, and to the left, for the space of about two inches, when it divides into two branches, called the right and left pulmonary arteries.

Course and Relations.—In its course, convex anteriorly and concave posteriorly, it is at first in front of the aorta, which it afterwards crosses, and then lies to its left side. At its point of division it lies beneath the transverse portion of the arch of the aorta, and is placed just below, and on a plane slightly anterior to, the division of the trachea. It is separated at this spot from the angle of bifurcation of the trachea, and from the left bronchus, by lymphatic glands and cellular tissue. Its bifurcation is not exactly opposite the bifurcation of the trachea, but rather to the left of it; it occupies the median line, whilst the trachea diverges slightly to the right side. At each side of the vessel, at its commencement, is the corresponding coronary artery, and its sides are in contact with the auricular appendages, the left auricular appendage overlapping it.

Up to its division the artery lies within the pericardium, enclosed together with the aorta in a single tube of the serous membrane; it is thus covered by it for some distance on its anterior surface only.

Passing from a spot situated a little to the left side of the median line of division of the artery, a fibrous cord exists, the obliterated remains of the *ductus arteriosus;* this cord proceeds from the upper border of the commencement of the left pulmonary artery to the lower border of the aorta, to which it is attached opposite the origin of the left subclavian artery.

Dimensions.—The length of the vessel is usually from two to two and a half inches, and its diameter from thirteen or fourteen lines.

The Right Pulmonary Artery passes from its origin outwards and slightly backwards, at a right angle, or very nearly so, to reach its destination in the root of its corresponding lung. In its course it passes through the arch of the aorta, above the right auricle, behind the superior vena cava, and in front, and below the level, of the right bronchus. At its termination it is in relation with the vena azygos, which lies above it. As the vessel reaches the lung it divides into two branches, an upper and a lower; the upper one is intended for the upper lobe, and soon divides into branches, which get behind the bronchial tubes and accompany them into the lungs; the lower branch descends, and after giving off a branch to the middle lobe passes behind the bronchial tube going to that lobe, and reaches the lower lobe, dividing into branches which accompany the bronchial tubes, getting to their posterior aspect.

Dimensions.—The length of the vessel is usually about eighteen to twenty lines, and its diameter from ten to twelve lines.

The Left Pulmonary Artery passes outwards and slightly backwards, at a right angle, or nearly so, to enter its lung. In its course it lies above the left auricle, and crosses in front of the aorta and left bronchus. As it reaches the lung it gets above the left bronchus, and gives off a branch or branches to the upper lobe; the continuation of the vessel then passes downwards behind the bronchus and enters the lower lobe of the lung.

Dimensions.—The length of the vessel is usually from eighteen to twenty lines; its diameter, from eight to nine lines.

The dimensions given can only be approximative, but they will be found to indicate the average dimensions in full-grown and well developed adults.

b. The Pulmonary Veins.

The Pulmonary Veins — arteriæ venosæ. — These are the vessels which convey the arterialised blood from the lungs to the left side of the heart. They commence in radicles in the interior of the lungs, at the periphery of the air-sacs, and ultimately terminate in four vessels, usually, which empty themselves into the left auricle. They exist in pairs, a pair belonging to each lung. In the following description only that portion is included which exists between the roots of the lungs and the left auricle.

Each pair of pulmonary veins is formed of an anterior and posterior branch.

The Right Veins.—The right anterior vein results from the junction of two branches, which are derived from vessels coming from the upper and middle lobes. The branches from the upper lobe pass downwards and inwards, lying in front of the vessels of the pulmonary artery; they unite to form one vessel. The branch from the middle lobe passes transversely inwards, and joins the one from the upper lobe; the vessel when formed lies on a plane anterior to, and below, the pulmonary artery and its branches of the same side; it passes inwards above the right auricle and behind the termination of the superior vena cava, and terminates in the right superior angle of the left auricle.

The right posterior vein is formed by the junction of several branches of considerable size from the lower lobe of the lung; these branches are placed on a plane behind the bronchus and pulmonary artery, and the trunk formed by them lies behind and below the latter structures; it passes upwards and forwards, above the upper border of the right auricle and behind the superior vena cava, and then enters the left auricle. Sometimes the anterior and posterior veins join before entering the auricle. The lower division of the right bronchus is placed between the anterior and posterior pulmonary veins of the same side. The two veins, before they enter the left auricle, perforate the fibrous portion of the pericardium, and get a covering of its serous layer, a process of the latter passing between them.

The Left Veins.—The left anterior pulmonary vein is formed by branches, usually two, from the upper lobe of the lung. These branches are, like those of the opposite vein, placed in front of the divisions of the bronchus and pulmonary artery. The vein, when formed, passes downwards and inwards, getting beneath and then somewhat behind the left pulmonary artery.

The left posterior vein is formed by branches from the inferior lobe; it ascends a little, passing forwards, crossing in front of the esophagus and aorta, and, converging nearly to the same spot as the anterior one, empties itself very near to it, into the left superior angle of the left auricle. Sometimes the two vessels form a single trunk before they terminate.

The lower division of the left bronchus lies between the two left pulmonary veins.

Before the veins enter the auricle they, like those of the opposite side, get a covering of the serous pericardium.

The pulmonary veins of both sides are of about the same length.

The Pulmonary Arteries within the Lungs.—The branches of each pulmonary artery, on entering the lungs, attach themselves to the bronchial tubes and their divisions, and accompany them throughout their course as far as their termination. This arrangement presents no exception in any part; the number of branches of artery is equal to the number of bronchial tubes; but at the termination of those tubes, where the air-sacs commence, a difference of arrangement exists.

Although every bronchial tube has its accompanying artery, yet these are not always given off at the same level as the tubes themselves. The vessels pass from the main trunk at obtuse angles; many of them have to pass partly round the air-tube which is the satellite of their trunk, to reach the tube for which they are destined.

Each branch of a pulmonary artery, as it accompanies a bronchial tube, distributes its branches in like manner with the tube itself, and thus often divides dichotomously; every lobule has its artery entering it, which at its entrance is a little less than the bronchial tube, but as the vessel gives off branches it gradually diminishes in size more rapidly than does the tube, so that at the termination of the latter the artery is not more than one-fifth the size of the tube.

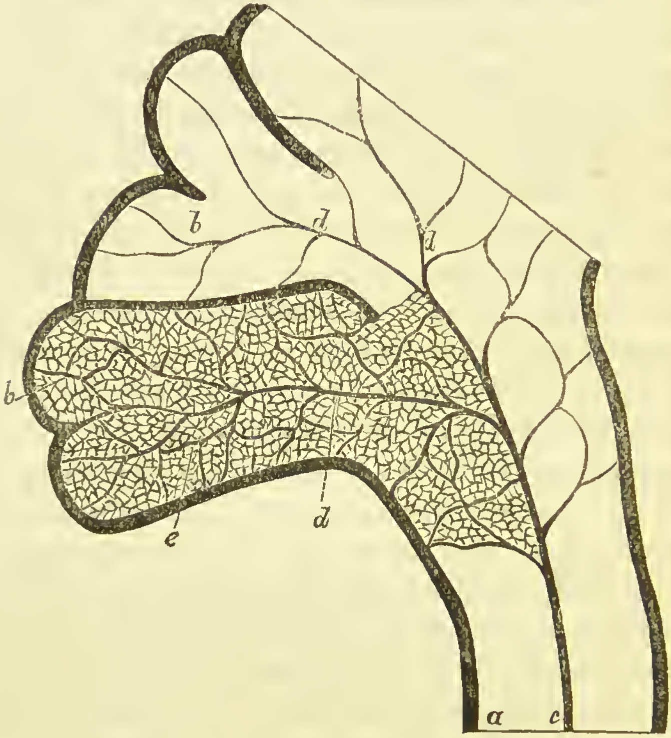
From the second and third divisions of the arteries some small vessels are given off, which do not correspond with any divisions of the air-tubes. These small vessels pass off nearly at right angles, and may be traced passing to portions of the pulmonary substance, which lie in close contiguity with the arteries.

The branches of the artery are connected with the bronchial tubes, and with the lung substance, by means of areolar tissue, which is loose and somewhat coarse in the larger vessels, near the root of the lung; but in proportion as the vessels become smaller, so does the connection become more and more intimate, and the tissue of union closer in its character, so that, when the artery reaches its lobule, it is closely applied to the parts with which it is in contact.

When the artery reaches the termination of the bronchial tube it gives off a number of branches, which are distributed to the air-sacs; before doing so, however, branches are derived from it which pass to the alveoli situated at the termination of the tube; these latter branches terminate in plexuses which are formed in the alveoli, and are arranged in a similar manner to those which exist in the air-sacs. The branches destined for the air-sacs take their course in the walls which separate the sacs from each other; they do not pass in any very regular or definite manner, but run in different parts of the sacs, and in different directions, along their entire length. Many of them may be observed passing straight from the commencement of the sacs to their fundus, and this course is more or less observed by all. In whatever way the *arterioles* pass, they gradually diminish in size as they proceed to the fundus of the sacs, and this diminution results from the giving off of a number of lateral branches from both sides of the vessel; these branches pass off at right or obtuse angles, and run in the walls of the sacs, they pass round the circumference of the sacs, and unite with branches coming from other arterioles, so that an imperfect and irregular network is formed by these primary branches of the arterioles; this network has been described by Rossignol, but I have not found it quite as regular as his description would lead us to infer. These branches are found running in the septa between the different alveoli, and branches sometimes cross through the middle of an alveolus,—this is the case whether we regard the alveoli placed at the sides or fundus of the sacs; the little vessels are placed in the substance of the partial septa. Independently of these branches, the saccular arteriole furnishes a number of smaller ones, which almost immediately after their origin terminate in a capillary plexus. (See Fig. 21.)

Arrangement of the Capillaries in the Air-sacs and Alveoli.—The pulmonary plexus, or *rete mirabile*, as

FIG. 21.*



---

* Fig 21 is a drawing of a terminal bronchial tube, and a portion of the air-sacs connected with it (of a cat). It shews the distribution of an ultimate branch of pulmonary artery; in one air-sac the arrangement of the pulmonary plexus is seen. *a.*, terminal bronchial tube; *b. b.*, air-sacs; *c.*, branch of pulmonary artery; *d. d.*. arterioles in air-sacs; *e.*, pulmonary plexus.

it has been very appropriately termed, is formed by the branching of the vessels above described. It is placed in the walls which separate the air-sacs, in the septa between the alveoli, and around the margins of the openings which exist in the sacs. The membrane in which the plexus lies is exceedingly thin, and the plexus consists of a single layer of vessels, which in no instance is doubled on itself. If a single alveolus be examined, it will be found that the vessels are spread out throughout its entire extent, and that the plexus rises in the septa surrounding it. In these septa, however, as well as at the margins of the circular orifices alluded to, the vascular network does not reach quite to the free border of the membrane composing them; in injected preparations, a small portion of transparent uninjected tissue is seen beyond the extreme vessels.

There is, as a rule, no distinct and separate vessel for each alveolus, no definite plexus consisting of afferent artery and efferent vein, belonging to each "vesicle," as was formerly supposed. The sacs of each *lobulette* get their vessels, which run irregularly through their walls, and apparently anastomose freely with the vessels belonging to adjoining lobulettes. The plexus is derived from the two sets of branches I have described as being given off from the arterioles; the vessels taking their course in the septa sometimes give off small branches, which run through the centre of the alveolus, and from each side of such a branch a network immediately arises, which spreads over the alveolus; sometimes, again, a separate branch from the arteriole itself may take this course, and be distributed in the same way; or again, the septal branch may at once give off a plexus, which spreads over the alveolus, and joins with a similar plexus coming from an opposite septal vessel; and these may be further reinforced by a plexus derived from a small lateral branch of the arteriole. These different arrangements may be seen in different alveoli of the same sac. From the vessels which cross the sacs, plexuses arise, which are spread out in the membrane forming the septa; and wherever an opening exists in a sac, and at the mouth of the sac, a plexus is formed from neighbouring vessels, and is spread out in the membrane which forms the opening, or the mouth.

The plexus, when formed, maintains a tolerably uniform size throughout. If examined in a well injected specimen which has been inflated and dried, it will be seen that the spaces between the vessels are somewhat greater in diameter than the vessels themselves. The meshes formed by the plexus are quadrilateral in shape for the most part; many of them are nearly square, but in others one diameter preponderates over the other.

The branches of the pulmonary artery do not anastomose until they reach the termination of the bronchial tubes. In the air-sacs their branches anastomose freely. It becomes difficult to decide whether the vessels belonging to one lobulette anastomose with those of another. In looking at a preparation which has been injected and dried, it seems as though the septum, separating one lobulette from another, resembled in every respect the walls of the air-sacs; but, considering that the lobulettes are originally formed as separate and independent bodies, as will be shewn in describing the fœtal lung, it appears probable that the vessels of one are distinct from, and independent of, those of the others. If this be the case, then the external walls of two adjoining lobulettes must have the capillary vessels of two sacs ramifying in them, or, in other words, there must be two walls brought in contact, with two layers of capillaries lying side by side, separated, however, from each other by the areolar tissue connecting the lobulettes, the quantity of such areolar tissue being very small.

This view militates against the general opinion, that in *no part* of the lungs is there more than a single layer of capillaries in connection with the aërating membrane, and that the air circulates on both sides of the plexus of the vessels; but yet, from the mode of formation of the lobulettes, and from the examination of some preparations of the lung substance of the adult, in which I have traced areolar tissue passing between the lobulettes, and have been able to separate them partially from each other, I am induced to believe that each lobulette has its separate vessels, which do not communicate with those of the adjoining ones, but terminate in their proper radicle vein, and that thus the capillaries, which are placed in the outer wall of the lobulette, are only exposed on one side to the atmosphere.

Whatever be the case with regard to the vessels of the different lobulettes, it is quite clear that the vessels of one lobule do not anastomose with those of another lobule, for when a portion only of a lung is injected, and the injection-pipe is placed in a small branch of the pulmonary artery, it will be found that the injection will fill a number of lobules supplied by the artery; but, lying by the side of these, others will be seen into which no injection will find its way; did the vessels of adjoining lobules anastomose, this would not be the case.

From the arrangement I have described, it will be seen that the pulmonary plexus is, for the most part, exposed to the air on both sides, a condition which is of the utmost importance with reference to the proper aëration of the blood. As the vessels lie in the walls of the air-sacs, and in the septa between the alveoli, the air circulates on both sides of them, in consequence of a single layer alone existing. This statement applies as a general rule, but if the opinion I have expressed above with reference to the external sacs of the lobulette be correct, then an exception exists to the double exposure of each blood-globule; and, moreover, there is another exception which I have not seen noticed, viz., in the vessels which are placed at the fundus of those sacs which are situated at the periphery of the lobules. It is clear that when the fundus rests on the sheath which invests the lobule, and which is separated from the sheath of the adjoining one by areolar tissue, or rests on the pleura, the vessels which are spread out on the alveoli of the fundus can only be exposed to the air on one side.

It appears, therefore, from these remarks, that some portion of the pulmonary plexus is not so arranged that its capillaries shall have air circulating on both sides of them, but that by far the greater portion of it is thus placed. It may further be remarked that, in all probability, before the blood reaches the fundus of the sacs I have alluded to, or even the periphery of the lobulettes, it has passed over other alveoli, and been aërated in them, and is, in fact, ready to be taken up by the pulmonary veins.

The branches of the pulmonary artery, which are distributed to the bronchial alveoli, anastomose freely at the mouths of the air-sacs with the capillary plexus formed in the walls of the sacs. The vessels distributed to the sacs themselves, and the plexus arising from them, pass from the apex to the fundus of each sac, and there terminate in the radicles of the pulmonary veins; in consequence of this arrangement the blood must pass through a series of alveoli before it is taken up by the last mentioned vessels, and thus it is exposed during a somewhat prolonged transit to the influence of the air. The remark which has been made by Dr. Williams is, in all probability, true, viz., that each drop of blood, in whatever part of the lung it may circulate, is arterialised to the same extent, from the equality of the aërating surfaces over which it passes.

Size of the Capillaries, and of the meshes of the Capillary Plexuses, of the Air-sacs.—From the examination of a number of preparations, which were injected, inflated, and dried, I have found the average diameter of the capillary blood-vessels varying from $\frac{1}{3000}$ to $\frac{1}{2500}$ of an inch, and the size of the meshes formed by the vascular network, that is, the spaces between the vessels, varying from $\frac{1}{2000}$ to $\frac{1}{1000}$ of an inch, the average being about $\frac{1}{1500}$ of an inch. In a preparation not inflated, the spaces between the blood-vessels seem much smaller, but the size presented in the inflated preparations is that which more accurately represents the actual condition of these parts.

The Pulmonary Veins within the Lungs. — The pulmonary veins take up the blood which has circulated in the walls of the air-sacs; they thus begin where the capillaries of the pulmonary plexus cease. They are found commencing in small radicles, which emerge from the peripheries of the different lobulettes; they take a short course, and empty themselves into a trunk which lies in an interlobular space; this trunk itself begins as a small radicle, and those commencing at the surface of the lung may be distinctly traced, arising from a set of air-sacs, and then dipping into an interlobular space. The vessel, having thus arisen, takes its course in the areolar tissue between the lobules, and as it passes on it is joined by a number of small veins, or venules, coming from different lobulettes. These venules join their trunks with very considerable regularity, and they may often be seen, in an injected preparation, emerging from the periphery of a set of air-sacs, and carrying off the injection which has passed to that set alone.

In a preparation in which the veins have been partially injected, so as only to fill the pulmonary plexus to a slight extent, the commencement of the veins is well seen; they are observed to begin in the walls of some of the air-sacs, and, increasing in size, they unite to form the various venules.

When the venous trunks are formed in the way I have mentioned, they continue their course in the spaces between the lobules, and, making their way in no regular manner, they take as direct a course as possible to the root of the lung. They are not, like the pulmonary arteries, associated, as a rule, with a bronchial tube; some of them may be found to be so, but such instances are exceptional.

The regular arrangement of bronchial tube, pulmonary artery, and pulmonary vein, which is mentioned by some authors, does not exist, except towards the root of the lung, when almost the entire space is occupied by vessels, and here, for a short distance, these structures are associated together. Some of the pulmonary veins are found taking a superficial course on the anterior part of the lung, and joining with the other veins to reach the left auricle; these vessels are usually small.

The pulmonary veins, as they take their course through the lungs, are surrounded by areolar tissue, which serves to connect them with the lung substance.

c. The Bronchial Vessels.

The bronchial system of vessels consists of *a. Arteries*, and *β. Veins*.

a. The Bronchial Arteries.—These vessels vary in their number and place of origin. On the right side, one artery is generally found, but in some instances two. The vessel (when one only exists) usually arises from the first aortic intercostal artery, or else by a common trunk with the left bronchial artery, from the thoracic aorta. Cruveilhier describes the vessel as occasionally arising from the subclavian, the internal mammary, or the second or third intercostal; he also states that he has seen the inferior thyroid give off a bronchial artery, which, after running along the trachea, passed in front of the right bronchus, and anastomosed freely with the right bronchial artery from the aorta. Haller has seen the vessels of both sides arise from the subclavian by a common trunk. Not unfrequently the vessels arise by a common trunk from the thoracic aorta.

On the left side there are usually two bronchial arteries, which arise from the aorta at different levels.

The vessel or vessels of the right side have a greater capacity than those of the left, in accordance with the relative size of the two lungs.

In whatever way the arteries arise, they pursue a somewhat tortuous course, and usually reach the posterior part of the bronchus, along which they run, and divide and subdivide with the successive ramifications of the bronchial tubes.

Distribution of the Bronchial Arteries and Veins, and their Mode of Communication with the Pulmonary System of Vessels.—Since the observations of Ruysch, Haller, and Sœmmering, a general opinion has been entertained that there was an anastomosis between the branches of the bronchial arteries and those of the pulmonary artery, and it has been, and still is, a disputed point with anatomists, whether such an anastomosis really exist. Doubt was first thrown on this apparently established fact by the experiments of

M. N. Guillot,* who found that injections thrown into the bronchial arteries never returned by the pulmonary artery. The assertions of this anatomist were doubted, and M. Huscke alleged, in confirmation of the previously received theory, that the capillary plexus of the bronchial tubes was continuous without line of demarcation with the plexus of the air-sacs and alveoli.

Rossignol made some experiments with reference to this subject, and the following are the results he obtained —

1. When the bronchial arteries were injected, the fluid returned in abundance by the pulmonary veins, in much less quantity by the bronchial veins, and no trace was found in the branches of the pulmonary artery.
2. When the pulmonary arteries were injected, the injection returned altogether by the pulmonary veins, and never by the bronchial arteries.
3. When the pulmonary veins were injected, the injection filled all the other vessels of the lung, the pulmonary artery, the bronchial arteries, and veins.

From these results he concludes that there is no direct communication between the bronchial arteries and the pulmonary arteries, but that there are numerous communications between the pulmonary veins and the bronchial vessels. He further remarks, that the communication is established between some of the pulmonary veins and the venous plexus which covers the membrane of the air-tubes, in fact, that some of the radicle bronchial veins empty themselves into the neighbouring pulmonary veins.[*]

---

* *Guillot. Journal d'Experiences*, No. 25. Quoted from Rossignol, Op. cit.

Adriani found that when the pulmonary artery was injected, the injection did not fill the bronchial vessels; but that when the pulmonary veins were injected, it did so; and that when the bronchial arteries were injected, the injection found its way into the pulmonary veins. He says, however, that all communication between the pulmonary arteries and the bronchial vessels cannot be denied; and, after describing the arrangement of the bronchial plexuses, he says that there are small branches of the pulmonary artery which perforate the muscular and elastic fibres, and anastomose with the plexus of the mucous membrane; and from this he concludes that the process of respiration, *i. e.*, of oxygenation of the blood, etc., goes on in the bronchial tubes as well as in the air-sacs. He believes that the superficial vessels of the bronchial tubes pour their contents into the pulmonary veins, whilst the deeper vessels terminate in the bronchial veins.[†]

In 1853, Dr. Heale presented to the Royal Society of London some observations on the distribution of the blood-vessels of the lungs; and as the views he entertains are of a somewhat novel character, and not in accordance with those of previous observers, nor yet with those which I shall have to maintain, I think it desirable to give them somewhat in detail, and almost as they appear in the published extracts of the Royal Society. He says —

---

[*] *Rossignol, Op. cit.*, p. 64.

[†] *Adriani. Op. cit.*

"The bronchial (so-called) arteries have their own special distribution; they do not supply in the smallest degree any portion of the *bronchial mucous membrane*, and they form no sort of communication either with the pulmonary arteries or veins, except as supplying their cellular sheaths, and therefore, in all probability, furnishing their *vasa vasorum*.

"The bronchial mucous membrane is very freely supplied with an exceedingly vascular plexus, of a peculiar and very characteristic description, which is found to ramify in every part of the bronchial membrane, and which may be traced even as high as the trachea. The whole of this plexus is derived from the air-cells, and terminates ultimately by means of minute radicles, which form trunks and join the *pulmonary veins*. No trace whatever of any branches of the pulmonary artery, previous to this becoming capillary in the air-cells, is found in any part of the bronchial membrane."

He says that the pulmonary veins are formed by two distinct sets of vessels; one set derived from the branches of the pulmonary artery distributed to the air-cells, the other consisting of vessels derived from the bases of the air-cells, which go to supply the bronchial mucous membrane, and terminate in radicles, as before mentioned. Thus the left auricle receives blood partly coming direct from the air-cells, and partly from the bronchial tubes.

He further states "that it is possible to inject entirely the pulmonary artery and veins without injecting the bronchial artery or veins; and it is also possible thoroughly to inject the latter without at all injecting the former, and when that is the case, *i. e.* when the bronchial arteries are injected while the pulmonary vessels are empty, it will be found that the bronchial membrane is wholly uninjected, however perfectly the (so-called) bronchial vessels may have been filled."

He adds, "The bronchial arteries, which are injected by filling the aorta, terminate in the veins which ramify in the sub-pleural cellular tissue; the greater part of these, after ramifying on the surface of the lung, beneath the pleura, pass along the broad band of pleura which extends from the peduncle of the lung to the posterior mediastinum. They empty themselves into the esophageal and other veins." *

Dr. Williams, in his article on the Organs of Respiration, in the Cyclopædia of Anatomy and Physiology, maintains that there are two systems or layers of capillary plexuses discoverable in the walls of the bronchial tubes, a superficial and a deep layer, and that the blood of the former empties itself into the pulmonary veins, and that of the latter returns by means of the bronchial veins. These views are the same as those advocated by Adriani.

According to Kölliker, the bronchial arteries are distributed, first, to the larger bronchial tubes, the vessels of which present the same conditions as those of the trachea, then to the pulmonary veins and arteries, and, lastly, to the pleura pulmonalis.

From the foregoing observations it will at once be seen that the distribution of the bronchial vessels demands further enquiry, and that the question of their communication, or otherwise, with the pulmonary system of vessels still requires elucidation. Having mentioned the results arrived at by previous observers, I now proceed to describe my own experiments, and the conclusions they have led me to make. My experiments have been conducted on the lungs of some of the lower animals, as the cat, the dog, the pig, the rabbit, the calf, and the sheep, as well as on those of man; they have been frequently repeated, and my observations have been made with all the care I have been able to bestow on them. I may state briefly the general results of my experiments, and then examine at length their indications.

---

* *Researches on the distribution of the Blood-vessels, &c., in the Lungs.* By J. N. Heale, M.D.—Abstracts of Papers communicated to the Royal Society of London, 1853, vol. vi. p. 315.

When the pulmonary artery is injected so that the fluid reaches the pulmonary plexus, but does not fill it completely, or at least does not pass through the plexus and fill more or less completely the pulmonary veins, the bronchial mucous membrane never becomes injected, nor does any portion of the bronchial tubes.

When, however, the artery is injected so as to fill the plexus and the pulmonary veins as well, the bronchial mucous membrane, and the other portions of the tubes, become partially injected.

When the pulmonary veins are injected, whether the pulmonary plexus be well injected or not, the deep vessels of the bronchial tubes, and the vessels of the bronchial mucous membrane, are always injected. The bronchial tubes are often seen to be injected when the pulmonary plexus is only very partially so, the fluid seeming to find its way from the pulmonary veins into the vessels of the bronchial tubes, more readily than into the capillaries of the air-sacs.

In a preparation that has been well injected through the pulmonary veins, the whole vascular system of the lungs becomes filled, viz., the branches of the pulmonary veins, the capillaries of the air-sacs, the pulmonary arteries, together with the vessels of the bronchial tubes, blood-vessels, lymphatics, and areolar tissue.

When the bronchial artery, or a branch of it as it enters a lobe of the lung, is injected, the vessels of the bronchial tubes become injected, both those of the mucous membrane and of the deeper structures, and the fluid finds its way into the pulmonary veins, which may become filled. If the injection be continued, it is possible to inject the pulmonary plexus through the medium of the bronchial arteries, and I have often found in such cases injection in the branches of the pulmonary artery. In addition to the vessels of the bronchial tubes becoming injected, those of the coats of the blood-vessels and lymphatics, and of the areolar tissue, become so.

In injecting the bronchial artery I have always found a difficulty, in the human lung, in properly filling the vessels along the whole length of the mucous membrane. I have traced vessels nearly to the extreme end of the bronchial tubes; but I have found that the mucous membrane has been best injected nearest the spot where the injection-pipe was inserted; in fact, that although the larger vessels were filled very nearly to the extremity of the tubes, the finer ones were only partially so. This seems to me to be due to the fact that, throughout the entire extent of the tubes, there is so free a communication between the bronchial vessels and the pulmonary veins, that the fluid finds its way into the latter more readily than into the fine plexus of the extreme bronchial tubes, the vessels of which are very small.

When the vena azygos is injected, and the injection finds its way into the bronchial veins, the bronchial tubes do not become injected, and on examining the course of the vessels which have been filled with the injection, I have never, in the observations I have made, found the so-called deep bronchial veins, as *venæ comites* of the bronchial artery. I have always found a small vein, or veins, most generally a single vessel, which accompanied the artery in its course along the bronchus; but it, or they, always appeared to me to terminate in the structures of the bronchus, and lower part of the trachea, and in the bronchial glands at the root of the lung. I have examined a large number of lungs, both of man and the lower mammalia, and I have always failed to discover any veins within the lungs accompanying the branches of the bronchial arteries. I have injected with fine injection, such as I have used for injecting the pulmonary capillaries, the vena azygos, on different occasions; I have found the bronchial vein, or veins, at the root of the lung filled, and on examining the bronchial tubes, the bronchus, and trachea, I have found the first uninjected, except just at their commencement, the second well injected, and the lower part of the last more or less so. In injecting a bronchial artery which was fairly within the lung, I have never found any return of the injection through a bronchial vein. These facts lead me to conclude that the so-called deep bronchial veins do not accompany the bronchial arteries within the lungs, and do not return any portion of the blood which is supplied to the bronchial tubes, but that they are simply vessels which return the blood from the structures situated about the root of the lung.

Course and Distribution of the Bronchial Arteries.—Each bronchial artery, when it reaches its bronchus, takes its course along it, lying at its posterior aspect, and, entering the lung, it divides and subdivides into branches, which accompany the bronchial tubes. The branches are small, and they lie close in contact with the outer wall of the tubes. Each branch of bronchial tube gets its branch of bronchial artery.

The vessels, as they pass along, give off branches, which run in the interlobular spaces, and supply the areolar tissue; they also give off branches, which are distributed to the coats of the blood-vessels, the nerves, and lymphatics.

If we examine the internal surface of the bronchial tubes, in a lung which has been well injected by the pulmonary veins or the bronchial artery, we find that there exists, in connection with the mucous membrane, a very fine plexus of capillary blood-vessels, which can be traced throughout the whole extent of the tubes; where the injection has been made through the pulmonary veins, this plexus is more completely filled, especially towards the termination of the tubes, than when made through the bronchial artery; but in the latter instance, numerous vessels are seen to be filled, especially in the larger tubes, and their arrangement is readily observed. If, now, we further examine this *superficial plexus*, and, whilst under the dissecting microscope, remove with a fine needle the plexus with the thin membrane in which it lies, we may see that its vessels communicate with other vessels which are more deeply seated. These latter I will call, for the sake of distinction, the *deep plexus;* they are found situated beneath and between the muscular fibres, and they take a circular direction round the tubes.

The *superficial plexus* of the bronchial tubes consists of a series of capillaries having a diameter varying from $\frac{1}{750}$ to $\frac{1}{1500}$ of an inch; they run for the most part in the longitudinal direction, taking, therefore, the line of the elastic fibres; they are connected with each other by means of cross branches, and the communications they thus establish are very frequent, so that a network of considerable regularity results.

This plexus is derived from the deeper set of vessels, which are seen, on dissection, to come towards the surface from the deep-seated parts. These latter vessels pass off from the trunk which accompanies the bronchial tube, and, after perforating the fibrous and muscular coats, reach the mucous membrane. The branches from which the plexus is immediately derived, are those which, after they have passed through the muscular coat, run between it and the elastic fibres; many of these, as they pass forwards, terminate somewhat suddenly by giving off a number of branches from their extremity, which pass in all directions, but for the most part longitudinally.

The *deep plexus* consists of vessels which are distributed to the muscular fibres, and the deeper portions of the tubes. The vessels which supply the muscles take a circular direction, for the most part, running beneath and between the fibres. They have a much greater diameter than the vessels of the mucous membrane.

It thus appears that there are two plexuses of vessels in connection with the bronchial tubes, one which belongs to the mucous membrane, the other to the deeper structures; but that they are both derived from the same source, and I believe they both terminate in a similar manner.

The bronchial arteries, as they accompany the bronchial tubes, give off branches which are distributed to the areolar tissue, and the various blood-vessels and lymphatics.

The pulmonary arteries get an abundant supply of blood, and a somewhat fine plexus is seen to be formed beneath their lining membrane. A plexus is also seen in connection with the pulmonary veins.

In the lungs of some of the lower mammalia I have succeeded in injecting thoroughly through the bronchial arteries the blood-vessels accompanying the lymphatics, and a somewhat fine network is formed of these vessels on the surface of the lung, where are also seen the vessels of the sub-pleural areolar tissue, which are continuous with those situated in the interlobular spaces. In the human lung

I have only occasionally, and that very partially, succeeded in injecting the blood-vessels of the lymphatics, through the bronchial arteries, but I have found them injected in preparations which have been injected through the pulmonary veins.

In the areolar tissue of the pleura a plexus of vessels of a somewhat fine character exists, and beneath these are seen the branches of the pulmonary veins. In the human lung I have only very rarely succeeded in injecting the vessels of the sub-pleural areolar tissue through the bronchial arteries; in some instances I have partially succeeded, and in injecting a lung which has been the subject of old standing pleuritic inflammation in spots, I have found the sub-pleural vessels injected at such spots. These vessels, however, although they cannot be easily injected through the bronchial arteries, may be easily filled through the pulmonary veins; they are continuous with those situated in the interlobular spaces, and they may be seen terminating in branches of the pulmonary veins.

I have mentioned that in injecting the bronchial arteries in the human lung I have not succeeded in injecting completely the vessels of the extreme bronchial tubes; the cause of this I shall endeavour to explain presently. With regard to the lungs of the lower mammalia — as the sheep, calf, and pig — I have experienced no difficulty whatever. When a bronchial artery of one of these animals is injected, the bronchial tubes are filled to their extremity, the fine plexus of the mucous membrane, however, being less completely filled than when the injection is thrown in by the pulmonary veins; the sub-pleural areolar tissue is also well injected, and the fluid finds its way into the pulmonary veins.

Having thus stated the results of my injections, it becomes an important question to consider *in what manner*, and *where*, the communication which undoubtedly exists between the pulmonary and bronchial vessels takes place.

If the statement I have made with reference to the bronchial veins be true, it is clear that those vessels do not return the blood supplied by the bronchial arteries, except so far as the latter vessels distribute it to the bronchi and the structures about the root of the lung; and the next point we have to examine is, whether any communication exist between the bronchial arteries and the pulmonary arteries. Do the former vessels pour their contents into the latter, which already contain venous blood, and therefore might be considered as fit receptacles for it? In all the best injections I have made of healthy lungs, whether of man or of the lower animals, in which the injection was introduced by a pulmonary artery, I have never found the bronchial tubes injected, except in those cases, as I have previously stated, where the injection has filled the pulmonary veins. I have mentioned that I have occasionally injected the branches of the pulmonary artery, through the bronchial artery—a result which would seem to indicate a communication between the two sets of vessels; I believe, however, that no direct communication exists, and that the result is produced by the fluid passing first into the pulmonary veins, and then through the pulmonary plexus, and thus into the pulmonary arteries.

Setting aside those cases of accidental extravasation, and of effusion of the injected fluid from the blood-vessels of the coats of the pulmonary arteries into the latter vessels, both of which accidents may take place, especially if the preparation be not quite fresh, I have found that when the bronchial artery was injected, the fluid *soon* returned by the pulmonary vein; when this was closed, and the injection continued for some time, and the piece examined as soon as the injection had set, I have found that the pulmonary veins were well filled, the pulmonary plexus partially so, and that the injection had found its way into the branches of the pulmonary artery.

From careful injection and examination of a considerable number of specimens, both of the human and other mammalian lungs, I have arrived at the conclusion that no direct communication exists between the bronchial vessels and pulmonary arteries.

We now pass on to consider the communication which undoubtedly exists between the bronchial vessels and the pulmonary veins. Some ingenious theories have been advanced with reference to this subject, which I shall have to examine hereafter. It is unquestionably more easy to inject the vessels of the small bronchial tubes through the pulmonary veins than through the bronchial arteries, and it is also quite possible to inject the tubes to a certain extent through those veins, without injecting the pulmonary plexus. On the other hand, the injection which is thrown in through the bronchial arteries rapidly and readily finds its way into the pulmonary veins. These facts seem to prove that the blood which is distributed by the bronchial arteries is poured into the pulmonary veins, and that the whole vascular system of the bronchial tubes communicates with the same veins. The question here arises, Do the pulmonary veins in any way supply the bronchial tubes? It has been asserted that the superficial plexus of the tubes is derived from the "air-cells," and that the blood, after ramifying over the mucous membrane, passes into radicle pulmonary veins. If it be so, it appears to me that we ought to be able to inject the plexus through the pulmonary artery, but this we are not able to do. Further, it has been stated that the bronchial arteries supply no part of the mucous membrane of the bronchial tubes; to this statement I cannot assent; I have several preparations in my possession, prepared by myself, which altogether negative the assertion.

The following, I believe, will be found to be true with reference to the distribution and termination of the bronchial arteries.

The bronchial arteries supply the whole of the structures of the bronchial tubes, the coats of the blood-vessels, the nerves and lymphatics, and the areolar tissue of the lungs, but not the air-sacs, which derive their nutrition from the pulmonary plexus.* These vessels (the bronchial arteries) form two plexuses in the air-tubes; one, which supplies the muscles and deeper structures, the other, the branches of which are very minute, the mucous membrane. The branches of these two plexuses, as well as the vessels which supply the other structures mentioned, all terminate in the pulmonary veins, and the reason why it is difficult to inject fully the bronchial mucous membrane throughout the whole extent of the tubes, appears to me to be that the capillaries of the membrane are exceedingly small, whilst the capillaries in which the other vessels terminate are of a coarser character, and very readily allow the injected fluid to pass through them into the veins; and a route being *once* established, the fluid is diverted from its course to the mucous membrane, and only fills a part of the vessels of that membrane.

---

* With regard to the nutrition of the air-sacs, no doubt can exist of the pulmonary vessels forming the source from which it is derived; no other vessels exist in the sacs, and in some

It has been stated, by Mr. Rainey, that the vessels of the bronchial tubes anastomose at their extremities with the vessels of the air-cells (air-sacs). In this statement I cannot concur. On examining a piece of injected lung, and following out the bronchial tube down to the air-sacs, under the microscope, it certainly does appear that the two sets of vessels communicate with each other; but still, if such were the case, would not an injection of the pulmonary artery inject a portion of the bronchial tubes? My belief is, that at the termination of the tubes, as elsewhere, the blood of the bronchial vessels is poured into the pulmonary veins.

animals the absence of bronchial arteries shews the capability of the pulmonary vessels for the function.

It may be said that such a view militates against the generally received opinion of the purity of the blood returned to the left side of the heart, for if the bronchial blood is poured into the pulmonary veins, it is returned to the left auricle without undergoing a process of aëration. I would answer, that the view I have taken is supported by anatomical fact, a basis on which all physiological theories should be founded.

That a distinct and free communication exists between the bronchial vessels and the pulmonary veins admits of ocular proof. I have seen, with the aid of the dissecting microscope, the small vessels passing from the outer surface of the bronchial tubes, and forming a small trunk, which terminated in a pulmonary vein.

The conclusions I have drawn seem to me to be warranted by the results of my experiments, but as they do not accord with the views of those authors whom I have quoted at the commencement of this section, I think it desirable to say a few words with respect to the latter.

The views expressed by Rossignol differ from my own in these respects — that he did not recognise that the whole of the blood, carried by the bronchial arteries into the interior of the lungs, was returned by the pulmonary veins, and that he has described the bronchial veins as existing within the lungs.

Again, Adriani describes a number of vessels as passing from the pulmonary artery to the bronchial mucous membrane, and ramifying in it. These vessels I have been unable to discover.

Dr. Heale has stated that the bronchial arteries do not supply the bronchial mucous membrane at all, and that they do not communicate with the pulmonary arteries or veins. I cannot but think that there must have been some error in Dr. Heale's injections when he obtained the results described in his paper; for not only do my injections most distinctly shew that a communication exists between the bronchial arteries and the pulmonary veins, but that the mucous membrane may be injected through the former.

With reference to the view which has been taken of this subject by Adriani and Dr. Williams, that the vessels of the bronchial mucous membrane terminate in the pulmonary veins, and those of the deeper plexus in the bronchial veins, it does not seem to me to be borne out by the injections I have made, which appear to prove that not only do the same vessels supply both the superficial and deep plexuses of the tubes, but that both plexuses discharge their contents into the same receptacles.

β. *The Bronchial Veins.*—The only vessels I have been able to discover to which this name can be applied are some small ones situated at the root of each lung, at its posterior aspect. I have previously mentioned that their distribution has always appeared to me to be confined to the structures about the root of the lung, the bronchi, the bronchial glands, etc., and that they do not return the blood from the interior of the lung. I have never seen, either in the lungs of man, or those of other mammalia I have examined, any veins accompany the several branches of the bronchial artery along the bronchial tubes.

Some veins have been described as passing away from the lungs in the layers of the *ligamentum latum pulmonis*, and joining the esophageal veins. As far as my observations go, these vessels do not return the blood from any part of the interior of the lungs, and are simply the small veins belonging to the areolar tissue between the folds of the ligament.

Since the foregoing was written, and consequently after the conclusions above mentioned had been arrived at, on perusing that portion of the Essay of Reisseisen in which he treats of the bronchial arteries, and which portion had not previously attracted my attention, I found the following passage, which I quote entire: —

"The veins which carry back the blood received from the bronchial arteries, since they have a special character, either neglected until now or else esteemed as an irregularity, seem most worthy of more accurate examination. For all the venules, which in the greatest portion of the lungs answer to the bronchial arteries, are collected not into similar trunks, but their mouths open into the pulmonary vein throughout its whole course. In that part only of the bronchial tubes nearest to the large vessels, and from a part of the vascular network, are the venules collected into a very small trunk, which passes into the vena azygos, or some other branch of the vena cava, or into the vena cava itself. It is called the bronchial vein."[*]

---

[*] "Venæ nunc quæ sanguinem ex arteriis bronchialibus acceptum revehunt, accuratiori examine, quum proprietatem referant, vel plane usque adhuc neglectam, vel certe pro aberratione habitam, dignissimæ videntur. Venulæ enim omnes, quæ maxima

In another part of his Essay he says—

"The course of the bronchial venules which I have described is constant, and not abnormal, and is observed in all the lower animals I have dissected."*

These observations of Reisseisen with respect to the bronchial veins accord with those I have previously made.†

---

pulmonum in parte arteriis respondent bronchialibus, non in similes truncos coëunt, sed in vena pulmonali per totum hujus decursum ora sua aperiunt. In parte tantum vasis majoribus. proxima bronchiorum et partim etiam reticuli vasculosi venulæ in communem, perexiguum sane truncum colliguntur, qui vel in venam azygon, vel aliquem venarum cavarum ramum, vel in ipsam venam cavam superiorem inseritur. Venam bronchialem dicunt."—*Op. cit.*, p. 14.

* "Venularum bronchialium decursus quem descripsi perpetuus neque præter naturæ normam est, et in omnibus quas dissecui bestiis observatur."—*Op. cit.*, p. 15.

† Although the passage I have quoted above would more properly have come at the commencement of this sub-section, where the views of previous observers are given, I have yet thought it desirable to leave it as it stands in the original Essay. When I commenced my investigations of the distribution of the bronchial vessels, I was under the impression that the deep bronchial veins accompanied the arteries within the lungs, and it was only from my inability to find them that I proceeded to make a more careful examination of their arrangement; and although I consulted most of the authors who had written on the lungs, yet I was unaware of the existence of the passage I have quoted above in the Essay of Reisseisen, and it was only after I had almost completed my experiments, and had arrived at the conclusions I have mentioned, that I discovered that that author had expressed opinions almost identical with my own. It appears strange that the views of this anatomist should not have been more generally accepted, but it seems to be due to the fact that they were comparatively unknown. It is a source of great satisfaction to me to find that opinions which were the result of careful examination and experiment are in accordance with those expressed by so distinguished an observer.

VIII. THE LYMPHATICS.

The Lymphatics: consist of two sets — the Superficial Lymphatics: Course, etc. — the Deep Lymphatics: Course, etc. — the Lymphatic Glands.

a. THE LYMPHATIC VESSELS.—These are divided into two sets—the superficial, and deep. The former ramify beneath the pleura, throughout the entire extent of the superficies of the lung. The latter are found chiefly accompanying the ramifications of the blood-vessels and air-tubes throughout the interior of the organ. The two sets of vessels communicate at various points with each other.

The superficial lymphatics are very large, larger than those of any other viscus; they are often distinctly seen in a recent lung, which has undergone no process of preparation. The vessels are found running round the margins of the lobules, and from them branches arise which form a plexus, which is spread over the surface of the lobules. The meshes of the network forming the plexus assume a polygonal form for the most part. The chief branches which result from these plexuses pass towards the inner edge and root of the lung, and there they unite with the vessels of the deep plexus.

The deep lymphatics are found accompanying for the most part the bronchial tubes and the branches of the pulmonary vessels; some are, however, found in the interlobular areolar tissue. They form branches of communication with the vessels of the superficial plexus. These lymphatics all pass through the glands situated around the primary bronchial tubes. At the root of the lung they join the superficial set of vessels, and accompany them to their destination.

The efferent vessels of the bronchial glands, having communicated with the glands in the posterior mediastinum, pass upwards on the trachea; having entered the cervical region, they unite freely with other lymphatics, and terminate on the left side in the thoracic duct, or separately in the large veins.

b. THE LYMPHATIC GLANDS. — Situated at the roots of the lungs, in the neighbourhood of the bronchi, and also surrounding the primary divisions of the bronchial tubes, numerous lymphatic glands are found. Some are placed at the posterior aspect of the bronchi, and in the angle of bifurcation of the trachea; others are situated around the bronchial tubes, just after they have entered the lungs. The former are usually the larger ones, and they receive the superficial lymphatic vessels; the latter receive the deep vessels which accompany the bronchial tubes and blood-vessels. All these glands are usually, after the adult period of life, found of a very dark colour, from the deposit of a pigment, resembling that described as existing in other parts of the lungs.

IX. The Nerves.

Their Source — they form two Plexuses — Course and Distribution of the Branches of the Plexuses — Observations of M. Sappey.

The nerves of the lungs are derived from the pneumogastric and the sympathetic.

The pneumogastric nerves, having entered the chest, take their course to the posterior part of the root of each lung, and they then divide into a large number of branches, by which plexuses are formed.

These plexuses are joined by branches coming from the great sympathetic, and, after this junction, the branches proceeding from the plexuses consist of fibres, in which the two sets of nerves are mingled.

Two plexuses are formed in connection with the root of each lung, called respectively anterior and posterior pulmonary plexus.

The anterior plexus consists of only a few small branches of nerves; it is situated on the anterior aspect of the root of the lung.

The posterior plexus is much the larger of the two; it is situated at the posterior aspect of the bronchus and lower part of the trachea. Branches of communication connect the plexuses of opposite sides.

From the above mentioned plexuses branches are derived, which supply the bronchial glands and the bronchi; and others, which accompany the bronchial tubes and the blood-vessels into the lungs. The branches of the posterior pulmonary plexus chiefly pass with the bronchial tubes; those of the anterior are for the most part lost on the pulmonary vessels.

Below the root of the lung branches pass between the layers of the *ligamentum latum pulmonis*, and reach the surface of the lung, where they become lost.

The branches of nerves which are derived from the pulmonary plexuses are distributed to the air-tubes, and the various vessels of the lungs. Those which accompany the bronchial tubes take their course for the most part in connection with the branches of the bronchial arteries, and they lie with the latter on the outer aspect of the tubes. As these trunks pass along in the course of the bronchial tubes, small branches are given off from them, which enter the substance of the tubes; they run in a slanting direction for some distance, and then, entering obliquely the structures of the tubes, are lost in the substance of the muscular and mucous coats. It is impossible, with the naked eye, to follow out the nerves in the smallest branches of the bronchial tubes, but in a preparation that has been injected, and which is dissected under the microscope (having been first submitted to the action of a solution of caustic soda), branches of nerves may be distinctly seen in the smaller bronchial divisions, but I have never been able to trace them with certainty in the finest ones. I have, however, no doubt of their existence up to the end of the bronchial tubes, but of their presence in the air-sacs proof seems to be wanting. In some of the lower animals, the branches of nerves accompanying the bronchial tubes may be traced with much greater facility than in man; in the sheep and calf I have traced them nearly to the extremity of the tubes.

The branches of nerves which accompany the blood-vessels are small. I have never been able to trace them far on the vessels; on the contrary, they have always appeared to me to be soon expended. I have found branches hooking round a vessel to reach a bronchial tube.

Reisscisen describes nerves as accompanying the vessels, which, he says, may be followed very far on them; and even when the unaided eye cannot follow them, their course may be ascertained by the two small vessels which accompany them, one lying on each side. He states that small branches are derived from these, which are lost between the fibres of the outer cellular membrane of the vessel, without it being possible to follow them.

In tracing out the nerves accompanying the bronchial tubes, I have found small branches passing off together with branches of the bronchial arteries, and these nerves have appeared to me, on careful dissection under the microscope, to be distributed to portions of the pulmonary tissue lying in the neighbourhood of the bronchial tube.

At the upper part of the root of the lung some branches of nerves are seen, passing along its upper border, and reaching the inner surface of the upper lobe of the lung, running towards its apex; these branches are small, they pass beneath the pleura, and seem to be lost on the surface of the lung. Other branches, apparently similarly distributed, pass, as I have before stated, between the layers of the *ligamentum latum pulmonis*, to the surface of the lower lobe. Whether these superficial nerves are distributed to the blood-vessels on the surface of the lung, or to the pleura, as some have supposed, or to both, I am unable to say positively; I have not been able to follow them to their ultimate divisions. Reisseisen has described these nerves, and he speaks of them as probably going to the capillary plexus on the surface of the lungs, and perhaps to the pleura—a view which was entertained by Willis.

An anatomist who has paid particular attention to the distribution of the pulmonary nerves, M. Sappey, describes them as accompanying constantly and exclusively the bronchial ramifications; as following them to their termination, without passing from them at a single point; as forming anastomoses on their surface; and lastly, exhausting themselves in their walls.*

With respect to the views of M. Sappey, I cannot admit the exclusive distribution of the nerves to the bronchial tubes; I have certainly seen branches, although not numerous ones, pass off from the trunks in the way I have described, and certainly also there are others which reach the superficial portions of the lungs. With regard to the blood-vessels, to which he gives no supply, although I cannot altogether agree with him, yet it has appeared to me that the nervous supply to these structures has been exaggerated by some authors, for I have never been able to trace the nerves beyond the primary branches.

---

* "Une étude speciale de la distribution de ces nerfs dans le poumon de l'homme, du bœuf, et du cheval, nous ayant permis de les suivre jusqu'à leurs dernières divisions, nous avons pu constater que dans les mammifères les ramifications nerveuses affectent avec les ramifications bronchiques les rapports les plus intimes; qu'elles s'appliquent constamment et exclusivement sur ces conduits pour les suivre jusqu'à leur terminaison, sans s'en écarter sur in seul point; qu'elles se divisent et s'anastomosent à leur surface en formant sur elles des arcades, des cercles, des ellipses qui l'entourent, et qu'elles s'épuisent enfin dans leurs parois."—*Recherches sur l'Appareil Respiratoire des Oiseaux.* Par. M. Sappey. Paris, 1847.

X. THE FŒTAL LUNGS.

The Pleura—the Trachea: Relations—the Bronchi—the Substance of the Lungs; Situation; Colour; Texture and Consistence; Weight, Absolute and Relative; Specific Gravity—the Air-tubes, Blood-vessels, and Ultimate Pulmonary Tissue.

Under this head I propose briefly to describe the fœtal lung as it exists at the ordinary period of birth, and in the later months of intra-uterine life.

THE PLEURA. — The arrangement and structure of this membrane are the same as it presents after birth and at adult life.

THE TRACHEA. — Before birth the trachea is unexpanded and flattened in the antero-posterior direction; it contains nothing but mucus, and its walls are in contact with each other; the posterior extremities of the cartilages also touch one another.

Relations. — The relations of the fœtal trachea are modified, both in the neck and thorax, by the existence of the thymus gland, and the small size of the larynx.

In the neck the thymus gland projects, in front of the trachea, from one-third to three-fourths of an inch above the level of the episternal notch, sometimes reaching as high as the lower border of the thyroid body, and being occasionally higher on one side than the other. It is placed close in contact with the tube beneath the sterno-hyoid and sterno-thyroid muscles.

The trachea is proportionately longer in the neck in the fœtus than in the adult. On account of the small development of the larynx, the tube is placed on a higher level than when the organ of voice is fully developed. It commences, as a rule, opposite the fourth or fifth cervical vertebra, but I have seen it extend as high as the third.

The relations of the trachea, above described, with reference to the thymus gland, prevail after birth, in a gradually decreasing degree, so long as the gland exists, and the length of the cervical portion of the tube does not reach its minimum until the larynx is fully formed after puberty.

In the thorax the trachea is proportionately shorter than in the adult. It has lying in front of it, close behind the sternum, the thymus gland, which is often found extending as low as the middle of that bone, and overlapping the upper part of the pericardium. It is not overlapped in front by the lungs, as these organs lie at the back of the chest. It usually bifurcates opposite the third dorsal vertebra.

THE BRONCHI.—The bronchi pass off from the trachea at very oblique angles to enter the lungs.

THE SUBSTANCE OF THE LUNGS: *Situation.*—The fœtal lungs are placed at the posterior and lateral parts of the thorax, and are separated from each other anteriorly and above by the thymus gland.

Colour.—The colour of the fœtal lungs is a dark red, or liver colour, becoming brighter on exposure to the air, from the oxygenation of the blood. The surface is marked by a number of dark lines, which bound a number of polygonal spaces. The lines denote the boundaries of the various lobules. Between these lines numerous smaller ones are found, which, on examination, prove to be small blood-vessels running underneath the pleura. The shape of the lobules on the surface of the lung may be distinctly seen; it varies much, — oval, roundish, quadrangular, hexagonal. The lobules are easily separated from each other.

Texture and Consistence.—In consistence the fœtal lung is dense and firm, and in appearance resembles more the liver than its own texture after respiration has taken place. This results from the entire absence of air; for, as we shall presently see, all the structures exist in their perfect integrity.

Weight: Absolute and Relative. — The absolute weight of the lungs at the ordinary period of birth varies with the size and development of the fœtus. I have found the average weight of the two lungs, in well developed fœtuses, about two ounces and five drachms to two ounces and seven drachms.

The Relative Weight of the Fœtal Lungs with respect to the entire Body.—The results of examinations into the relative weight of the fœtal lungs are not satisfactory. The following have been given by Meckel —

In an embryo of 16 lines - - - -	1 to 25
„ „ 29 „ - - - - -	1 to 27
„ „ 40 „ - - - - -	1 to 43
„ „ 4 inches - - -	1 to 41½
„ „ at end of 9th month	1 to 70
In the newly-born - - - - - - -	1 to 35

Ploucquet gives the average as 1 to 70 in full grown fœtuses which have not breathed, and 1 to 35 after respiration.

Specific Gravity.—Quain states that the specific gravity of the fœtal lung is 1.056. In a recent specimen I examined I found it 1.062.

THE AIR-TUBES, BLOOD-VESSELS, AND ULTIMATE PULMONARY TISSUE.—No description is here required of the arrangement and distribution of the bronchial tubes, of the various blood-vessels, nerves, etc., of the fœtal lungs; they are the same as after birth, except that the pulmonary vessels are proportionately smaller in size, from the fact that they have not yet assumed their full function. The intimate structure of the parts is also the same as obtains in after life.

It becomes a very important question, and one the elucidation of which is likely to throw much light on the arrangement of the ultimate air-tubes, whether the air-sacs are already formed in the fœtal lung, or whether they are the result of the expansion which takes place when respiration is established. It was first proved by Mr. Rainey, and subsequently by others, that the ultimate pulmonary tissue was fully developed before birth, and ready to perform its function when called upon. It is not, therefore, that the first inspiration distends a quantity of irregularly formed tissue, and that the air-sacs are produced as the result of pressure, but they exist in a collapsed state, in separate groups, attached to their bronchial tube, with their organisation of alveoli, etc., complete.

If a recent fœtal lung be placed under the microscope, or examined with a lens, no appearance of air-sacs, or vesicles, or cells is seen. It presents the aspect of a liver-like mass, having the markings I have previously described.

If now the lung be gently inflated (being first soaked in warm water for some time, so as to soften it, and prevent rupture of any of its structures), and placed under the microscope, different appearances will present themselves, according as the inflation has been partial or entire. In a portion of lung only partially inflated, a number of distinct tubes will be observed, under the pleura, terminating beneath the pleura in cœcal extremities; they have a light-coloured appearance, and thus contrast strongly with the dark-coloured surrounding tissue. In some instances the exact arrangement of these tubes may be seen; they will be found to exist in clusters or groups, and are seen to pass from the cœcal ends to a point in which they terminate, and at which they seem all to join; or, to describe them in the inverse direction, they pass from a point at some distance from the surface, and radiate towards the pleura. In some parts, when the lung has been but very little inflated, only a few tubes are seen — perhaps three or four — and these are often seen to have small diverticula or *cœcums* passing from them at different parts of their circumference. The tubes are observed to have constrictions in numerous places, and to bulge in the intervals between the constrictions; they terminate in extremities rounded, or nearly so. In a preparation of this kind it is often easy to see the bronchial tube for a short distance before it terminates, and not only is the terminal lobulette visible, but two or more of the previous ones, arising laterally from the bronchial tube, may be also seen. The uninflated lung substance lying between the distended tubes may be distinctly recognised where there has been only slight inflation, and the isolated condition of each group of tubes is very apparent; the tubes passing from different points are seen taking different directions.

If now the inflation be carried further, the number of tubes visible becomes greater; they are seen to lie close together, and the shape assumed by each group is observed. They still present the appearance of a number of small tubes terminating in culs-de-sac.

If the inflation of a piece of lung be carried to the full extent, so as to distend it perfectly, the appearance just described disappears, and the ordinary appearance in an inflated lung presents itself, except that the "vesicles" are smaller. The grouped arrangement is no longer visible, because, the whole of the air-sacs being distended, and the partitions between the different groups being but little, if any, thicker than the walls between two sacs, the line of separation does not appear—just as obtains in the adult lung. On careful examination, especially of the partially distended groups, the walls of the sacs may be seen to be sacculated, and the oblique or vertical course of the sacs, with reference to the pleura, is apparent.

If we take a fœtal lung, and follow out the course of one of its bronchial tubes, we find that the smaller branches of the tube have connected with them clusters of little pyriform, red-coloured bodies, which look very much like a number of small grapes attached to their stalks. In a fœtus of six months I have found it somewhat difficult to separate each individual body, but in a full-grown fœtus there is no difficulty in doing so. Each little body is found attached to a short pedicle. If air be blown down a bronchial tube leading to the bodies which have been exposed, the latter become distended, thus demonstrating their communication with the former.

The little bodies above described are the ready-formed groups of air-sacs; the pedicle with which each is connected is the terminal bronchial twig, and the clusters spoken of constitute the different lobules. In a young fœtus, the lobules connected with a large bronchial tube may be separated from those which belong to another bronchial tube.

From this description it will be seen that the air-sacs are fully formed before birth; that each terminal bronchial tube has its little pyriform body of undistended air-sacs connected with it; and that each group, forming what I have elsewhere, in speaking of the lung after birth, called a *lobulette*, is surrounded by a sheath, and that thus no communication can exist between it and adjoining ones.

The examination of the fœtal lung in the manner I have described seems to me to afford an additional proof of that view of the arrangement of the air-sacs which I have elsewhere detailed. I may, perhaps, be asked how I can account for the different appearances assumed by the lung under different degrees of inflation. Before I attempt to explain the phenomena, I may state that I have found the artificial inflation I have practised entirely accord in its results with that effected naturally, thus proving that the appearances I have described have not been produced by any unfair agency. I have recently had an opportunity of examining the lungs of an infant in which no artificial respiration had been practised, and which had never fully breathed. Some portions of the lungs were altogether undistended, but other parts were partially, and some few spots fully, distended. I found the same appearances in them when I examined them under the microscope as I had found in the lungs I had myself inflated.

The different appearances I have described are entirely due to the different degrees of inflation of the air-sacs. If only one or two sacs are distended, an appearance will be presented of one or two isolated tubes terminating in culs-de-sac, continued from the extremity of the bronchial tube, the remaining sacs of the lobulette being collapsed. If, on the other hand, more become distended, then other sacs previously unseen become apparent, until at length none remain in a collapsed state; and when this is the case, as the sacs of each lobulette meet each other at their sides, no space is left between them except their septum, and no line of demarcation can usually be made out.

The appearances which the ultimate air-tubes present in a fœtal lung in the various conditions of *non-perfect* inflation, resemble very much those of the terminal ducts of ordinary compound glands, and an erroneous impression of the nature of the air-sacs might easily be formed, unless due regard were had to their condition under *perfect* inflation.

I have specimens in my possession of the fœtal lung, prepared in the same way as those of the adult from which I have drawn up my previous description, viz., injected, inflated and dried; they present the same appearances when sections of them are made as the others to which I have alluded.

XI. The Development of the Lungs.

Development of the Lungs in Birds and Mammals—Views of Von Baër, Valentin, Rathké, Müller, Reichart, Bischoff, Kölliker, Mandl—Investigations of the Author.

Although this subject does not strictly come within the limits of an essay on the anatomy of the lung, yet I have thought it desirable to add a brief consideration of it.

The following statement, with reference to the development of the lungs, is the result partly of my own investigations, and partly of the observations of those authors whom I have consulted. As it was necessary that the essay should be completed by a certain date, I found that I had not sufficient time to examine the subject thoroughly, and I was compelled to rest satisfied with only a partial investigation. Since the essay was sent in, I have been unable to resume my observations on this subject, and am compelled to send them to the press as they stand.

My own statements are deduced from a series of observations on the embryo chick, at periods varying from the third up to the eleventh day of incubation, and on a number of specimens of human and other mammalian embryos at an early period of uterine existence.

The development of the lungs in the chick seems to take place in the following manner. They first make their appearance as two small protrusions from the esophageal portions of the alimentary canal.

These protrusions were originally described by Von Baër as hollow, and communicating from the first with the esophagus; in fact, as forming diverticula from that tube, and being lined by its inner membrane.* According to this view, which was supported by Valentin, Rathké, and Müller, these diverticula formed the commencement of the trachea and bronchi, and, by their prolongation downwards, and subsequent division, the bronchial tubes and their ultimate ramifications. This view of the formation of these parts was disputed, first by Reichert,† and subsequently by Bischoff,‡ who expressed opinions that the rudiments of the lungs were solid, and formed of a mass of cells, which in the beginning did not communicate with the esophagus, nor contain any cavity.

According to Bischoff, the lungs of embryo birds and mammals present themselves in the form of tubercles situated at the upper part of the intestines, and are formed of a blastema, proceeding from the bulging or budding of the external intestinal wall, into which bulging the internal membrane does not penetrate. He thought it doubtful whether a communication became established between the pulmonary tubercles and the intestinal cavity, because in other glands it is the inner intestinal covering which offers the first traces of development, and because a short time only elapses before the tubercles have contracted connection with the trachea which extends from below upwards, and cease to have any with the esophagus. The bronchial tubes are therefore developed, according to this view, without any projection into them of the internal coat of the intestine. The trachea seems also to be formed, according to the same view, by a similar budding, and the two organs are soon detached from the intestinal wall, and they then become independent. In mammalia the lungs appear about the same time as the liver. They increase in growth slowly, and are for some time entirely hidden by the heart and liver.

---

* *Baër. Entwickelungsgeschichte. Kœnisberg*, 1828–37, vol. i., p. 6.

† *Reichert. Das Entwickelungsleben ir Wirbelthierreich. Berlin*, 1840, p. 193.

‡ *Bischoff. Developpement de l'Homme et des Mammifères. Encyc. Anat. Trad.*, par A. J. L. Jourdan, tome viii.

According to Bischoff, the rudiments of the lungs are at first smooth and undivided on their surface; they are composed of a blastema formed of cells. The trachea is also formed of similar cells. The future cavity shews itself in the long axis of the organ, and is recognised by its deeper colour; and is probably produced by the deliquescence of the materials of the blastema. The first rudiments of the bronchial tubes send off projections, from the sides and extremities, like other glands, apparently by appropriating to themselves the cells which constitute the blastema. These projections or buddings represent the ramifications of the bronchial tubes, and the future cavity is seen to be forming in the interior. A lobule of the fresh lung, examined by transmitted light, with sufficient power, shews on the exterior a clear tongue-like portion, formed of the blastema; then comes a portion deeper in colour, which surrounds the bronchial ramification; then the bronchial ramification, remarkable for its clear colour, the axis of which offers a darker colour, announcing the cavity which is forming. The bronchial tubes multiply themselves, but the last shoots alone constitute the pulmonary cells, which hold the same relative position as glandular vesicles. Bischoff thinks that the pulmonary cells owe their birth to the fusion of the cells of the blastema, but later they are formed of a proper tissue, homogeneous and simple. There is this difference between them and glandular vesicles, that whereas the latter, even when they are covered by an epithelium, enclose always elementary granulations and nuclei, the pulmonary cells are only covered by an epithelium, and a veritable cavity is developed in them, into which air penetrates after birth. Bischoff does not assign any exact date to the development of the pulmonary cells, but he thinks it is towards the sixth month, when, according to Rathké, a little air can be blown into the lungs.

The rudiments of the lungs are at first smooth, but they soon present inequalities, which answer to the primary ramifications of the bronchial tubes; these become more marked, and the lobes are indicated; the process goes on in the lobes, and the subdivision into lobules takes place.*

In a work † written subsequently to the one I have quoted from, Bischoff abandons his former opinions with respect to the original formation of the lungs. He now believes that they are hollow buddings, or projections, as Baër first stated. Remak is also of the same opinion. As with the liver, and other glands, they believe that the mucous fold of the intestines forms the parenchyma, whilst the external fold is the source of the vessels, nerves, and fibrous envelope.

---

* *Bischoff. Op. cit.*

† *Bischoff. Entwickelungsgeschichte des Hundeeies*, page 105. *Brunswick*, 1845. Quoted by Mandl, *Op. cit.*

Kölliker is of opinion that the lungs appear as hollow protrusions from the intestinal canal, a short time after the liver. He has seen, in the smallest lobules of early embryos, the bronchial tubes terminate in culs-de-sac. The lobules multiply themselves by budding of the bronchial tubes. These buds are hollow and lined with a cylinder epithelium, and are dilated at their extremity. The development of the lungs resembles that of compound glands. The air-sacs do not appear till the sixth month.

Mandl has examined with care the lungs of early mammalian embryos. He found in the lung of a lamb, on examining the terminal buddings of the bronchial tubes, that the interior of the buds was hollow. In making a transverse or longitudinal section of one of these culs-de-sac, he recognised an external membrane which formed the contour, a parenchyma composed of granules, corpuscles, and cells, and lastly, in the centre, a very narrow slit.

In speaking of the further development of the lobules, with their vesicles, he says, " no doubt the multiplication of vesicles (utricles) takes place by subdivision of the primitive vesicle into two or four secondary vesicles." *

The examinations I have been able to make are not sufficient to enable me to express an opinion as

---

* *Mandl. Anat. Micros.*, vol. ii. (*Develop. des Poumons.*)

to the mode in which the lungs begin to form. I have observed on the fourth day, in the chick, the lungs projecting as little bodies in front of the esophagus (Figs. 22, 23, 24), and on the fifth or sixth day I have found them separated from the esophagus, and each possessing its bronchus. (See Fig. 25.)

Fig 22.*

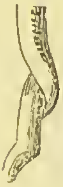


Fig. 23.†

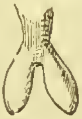


Fig. 24.†

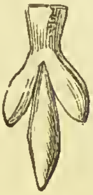
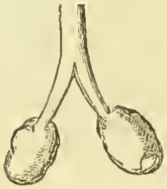
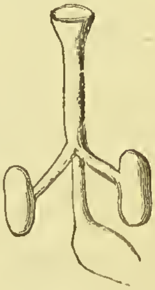


Fig. 25.‡



The rudimentary lungs at first have a smooth appearance, but as they progress in growth they begin to assume a slightly nodulated or granular aspect. About the tenth or eleventh day, the lungs have become considerably developed in the chick, and the ramifications of the bronchial tubes have assumed nearly their permanent character and situation. The glottis makes its appearance about the fifth day, and is then observed as a mere slit; examined on the eighth day, the rudimentary larynx is found developed, as represented in Fig. 26.

Fig. 26.§



---

* Fig. 22 represents the lungs of the chick, as seen at the fourth day of incubation (side view).

† Figs. 23 and 24, ditto ditto (anterior view).

‡ Fig. 25, ditto ditto, at sixth day.

§ Fig. 26, ditto ditto, at eighth day.

In early human embryos I have observed the terminal culs-de-sac of the bronchial ramifications, which I believe to be hollow; I have also found that in fœtuses at the sixth month it is quite possible to inflate the lungs to a considerable extent; and I believe the air-sacs are tolerably well formed at that period, for I have found nearly the same result from an inflation of them as from an inflation of the lungs at a later period of uterine life. I believe that each terminal bud or cul-de-sac of a bronchial tube forms the rudiment of a lobulette, or group of air-sacs, and that the latter are formed by projections of the lining membrane into the interior of the cavity which exists in the bud; a number of these projections thus growing form the walls of the various air-sacs. I believe the alveoli are formed in a similar manner, by the

Fig. 27.*

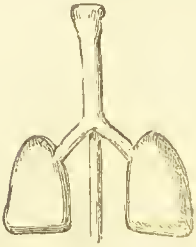


Fig. 28†.

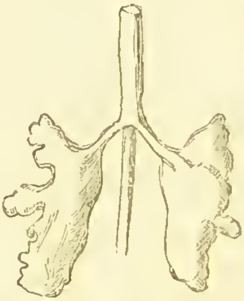


Fig. 29.*

---

* Fig. 27. Lungs of human embryo, at about the sixth or seventh week.

† Fig. 28. Ditto of embryo cat.

‡ Fig. 29. A bronchus and its terminations in a very young pig (after a drawing in *Carpenter's Human Physiol.*)

ingrowing at different parts of the membrane which forms the walls of the air-sacs.

The precise mode of origin and formation of the trachea is somewhat doubtful. Baër regards it as a tubular prolongation from the esophagus, and others believe it to be formed upon the esophagus, and to open into it subsequently. According to Valentin and Rathké, the rings of the trachea begin as simple tongue-shaped portions, which pass through all the stages of formation of cartilage; whilst, on the other hand, it has been maintained that the rings result from the junction of two lateral halves, which may be distinguished for the first time in the fourth week in the human embryo.

In the chick, the early cartilaginous rings do not appear till after the twelfth day of incubation; they are first seen as transverse striæ, in the median line of the front only; they gradually become solid, and extend themselves outwards and backwards.

CONCLUSIONS.

The lungs consist of two portions—

1st. That which constitutes the CONVECTIVE CHANNELS, by means of which the air is carried to and from the true respiratory portion.

2nd. THE TRUE RESPIRATORY PORTION—that in which the process of respiration is carried on.

The first portion is formed of *the Trachea*, *the Bronchi*, and *the Bronchial Tubes.*

The second portion is formed of the *terminal dilatations of the Bronchial Tubes*, *together with a number of tubes given off from them*, to which the name of AIR-SACS has been given, to each assemblage of which the term LOBULETTE has been applied; the terminal dilatation of the bronchial tube is, in fact, but the commencement of the lobulette, or the *point de reunion* of the various air-sacs.

The *Convective Channels* consist of cartilaginous rings, muscular and fibrous tissue, and a mucous membrane which is lined by a columnar ciliated epithelium.

The *Respiratory Portion* presents on the parietes of the parts of which it is composed a number of depressions, to which the term ALVEOLI has been given; these *alveoli* exist in the air-sacs, and in the terminal dilatation of the bronchial tubes, and in some animals in the ultimate bronchial tubes, previous to their dilatation.

The *Air-sacs* and the *alveolated portion of the*

Bronchial Tubes are lined by a variety of the pavement epithelium.

The *Pulmonary Artery* distributes its blood to the respiratory portion of the lungs.

The *Pulmonary Veins* return the blood which has been distributed by the pulmonary artery.

The ultimate branches of the pulmonary artery in the air-sacs form the nutritious vessels of the respiratory portion of the lungs.

The *Bronchial Arteries* distribute their blood to the bronchi, the bronchial tubes, the vessels and areolar tissue of the lungs; the branches that enter the lungs pour their contents into the pulmonary veins.

The *Bronchial Veins* return the blood which is distributed to the structures about the roots of the lungs.

The *Lymphatic Vessels* of the lungs form two sets, a superficial and deep. The former are found at the surface of the lungs; the latter chiefly accompany the bronchial tubes.

The *Nerves* of the lungs are derived from the pneumogastric and sympathetic; branches are distributed chiefly to the bronchial tubes, but some pass to the blood-vessels and to the surface of the lungs; some apparently are lost in the pulmonary tissue.

The air-sacs exist fully developed in the fœtal lung before birth.

THE END.

WELLCOME LIBRARY INSTITUTE

D. MARPLES, PRINTER, LIVERPOOL.

CATALOGUE C]

LONDON, *August*, 1886.

J. & A. CHURCHILL'S
MEDICAL CLASS BOOKS.

ANATOMY.

BRAUNE.—An Atlas of Topographical Anatomy, after Plane Sections of Frozen Bodies. By WILHELM BRAUNE, Professor of Anatomy in the University of Leipzig. Translated by EDWARD BELLAMY, F.R.C.S., and Member of the Board of Examiners; Surgeon to Charing Cross Hospital, and Lecturer on Anatomy in its School. With 34 Photo-lithographic Plates and 46 Woodcuts. Large Imp. 8vo, 40s.

FLOWER.—Diagrams of the Nerves of the Human Body, exhibiting their Origin, Divisions, and Connexions, with their Distribution to the various Regions of the Cutaneous Surface, and to all the Muscles. By WILLIAM H. FLOWER, F.R.C.S., F.R.S. Third Edition, containing 6 Plates. Royal 4to, 12s.

GODLEE.—An Atlas of Human Anatomy: illustrating most of the ordinary Dissections and many not usually practised by the Student. By RICKMAN J. GODLEE, M.S., F.R.C S., Assistant-Surgeon to University College Hospital, and Senior Demonstrator of Anatomy in University College. With 48 Imp. 4to Coloured Plates, containing 112 Figures, and a Volume of Explanatory Text, with many Engravings. 8vo. £4 14s. 6d.

HEATH.—Practical Anatomy: a Manual of Dissections. By CHRISTOPHER HEATH, F.R.C.S., Holme Professor of Clinical Surgery in University College and Surgeon to the Hospital. Sixth Edition, revised by RICKMAN J. GODLEE, M.S. Lond., F.R.C.S., Demonstrator of Anatomy in University College, and Assistant Surgeon to the Hospital. With 24 Coloured Plates and 274 Engravings. Crown 8vo, 15s.

ANATOMY—*continued.*

HOLDEN.—A Manual of the Dissection of the Human Body. By LUTHER HOLDEN, F.R.C.S., Consulting-Surgeon to St. Bartholomew's Hospital. Fifth Edition, by JOHN LANGTON, F.R.C.S., Surgeon to, and Lecturer on Anatomy at, St. Bartholomew's Hospital. With 208 Engravings. 8vo, 20s.

By the same Author.

Human Osteology: comprising a Description of the Bones, with Delineations of the Attachments of the Muscles, the General and Microscopical Structure of Bone and its Development. Sixth Edition, revised by the Author and JAMES SHUTER, F.R.C.S., late Assistant-Surgeon to St. Bartholomew's Hospital. With 61 Lithographic Plates and 89 Engravings. Royal 8vo, 16s.

MORRIS.—The Anatomy of the Joints of Man. By HENRY MORRIS, M.A., F.R.C.S., Surgeon to, and Lecturer on Anatomy and Practical Surgery at, the Middlesex Hospital. With 44 Plates (19 Coloured) and Engravings. 8vo, 16s.

The Anatomical Remembrancer; or, Complete Pocket Anatomist. Eighth Edition. 32mo, 3s. 6d.

WAGSTAFFE.—The Student's Guide to Human Osteology. By WM. WARWICK WAGSTAFFE, F.R.C.S., late Assistant-Surgeon to, and Lecturer on Anatomy at, St. Thomas's Hospital. With 23 Plates and 66 Engravings. Fcap. 8vo, 10s. 6d

WILSON — BUCHANAN — CLARK. — Wilson's Anatomist's Vade-Mecum: a System of Human Anatomy. Tenth Edition, by GEORGE BUCHANAN, Professor of Clinical Surgery in the University of Glasgow, and HENRY E. CLARK, M.R.C.S., Lecturer on Anatomy in the Glasgow Royal Infirmary School of Medicine. With 450 Engravings, including 26 Coloured Plates. Crown 8vo, 18s.

BOTANY.

BENTLEY AND TRIMEN.—Medicinal Plants: being descriptions, with original Figures, of the Principal Plants employed in Medicine, and an account of their Properties and Uses. By ROBERT BENTLEY, F.L.S., and HENRY TRIMEN, M.B., F.L.S. In 4 Vols., large 8vo, with 306 Coloured Plates, bound in half morocco, gilt edges, £11 11s.

BOTANY—*continued.*

BENTLEY.—A Manual of Botany. By Robert BENTLEY, F.L.S., M.R.C.S., Professor of Botany in King's College and to the Pharmaceutical Society. With 1185 Engravings. Fourth Edition. Crown 8vo, 15s.

By the same Author.

The Student's Guide to Structural, Morphological, and Physiological Botany. With 660 Engravings. Fcap. 8vo, 7s. 6d.

ALSO,

The Student's Guide to Systematic Botany, including the Classification of Plants and Descriptive Botany. With 357 Engravings. Fcap. 8vo, 3s. 6d.

CHEMISTRY.

BERNAYS.—Notes for Students in Chemistry; being a Syllabus of Chemistry compiled mainly from the Manuals of Fownes-Watts, Miller, Wurz, and Schorlemmer. By ALBERT J. BERNAYS, Ph.D., Professor of Chemistry at St. Thomas's Hospital. Sixth Edition. Fcap. 8vo, 3s. 6d.

By the same Author.

Notes on Analytical Chemistry for Students in Medicine. Second Edition. Crown 8vo, 4s. 6d.

BLOXAM.—Chemistry, Inorganic and Organic; with Experiments. By CHARLES L. BLOXAM, Professor of Chemistry in King's College. Fifth Edition. With 292 Engravings. 8vo, 16s.

By the same Author.

Laboratory Teaching; or, Progressive Exercises in Practical Chemistry. Fifth Edition. With 89 Engravings. Crown 8vo, 5s. 6d.

BOWMAN AND BLOXAM.—Practical Chemistry, including Analysis. By JOHN E. BOWMAN, and CHARLES L. BLOXAM, Professor of Chemistry in King's College. Eighth Edition. With 90 Engravings. Fcap. 8vo, 5s. 6d.

BROWN. — Practical Chemistry: Analytical Tables and Exercises for Students. By J. CAMPBELL BROWN, D.Sc. Lond., Professor of Chemistry in University College, Liverpool. Second Edition. 8vo, 2s. 6d.

CHEMISTRY—*continued.*

CLOWES.—Practical Chemistry and Qualitative Inorganic Analysis. Adapted for use in the Laboratories of Schools and Colleges. By FRANK CLOWES, D.Sc. Lond., Professor of Chemistry in University College, Nottingham. Fourth Edition. With Engravings. Post 8vo, 7s. 6d.

FOWNES.—Manual of Chemistry.—*See WATTS.*

FRANKLAND AND JAPP.—Inorganic Chemistry. By EDWARD FRANKLAND, Ph.D., D.C.L., F.R.S., and F. R. JAPP, M.A., Ph.D., F.I.C. With 2 Lithographic Plates and numerous Wood Engravings. 8vo, 24s.

JAMES.—Notes on the Detection of the Acids (Inorganic and Organic) usually met with in Analysis. For the use of Laboratory Students. By J. WILLIAM JAMES, Ph.D., F.C.S., Demonstrator and Assistant Lecturer in University College, Cardiff. 8vo, 1s.

MORLEY.—Outlines of Organic Chemistry. By H. FORSTER MORLEY, M.A., D.Sc., Assistant Professor of Chemistry at University College, London. Crown 8vo, 7s. 6d.

TIDY.—A Handbook of Modern Chemistry, Inorganic and Organic. By C. MEYMOTT TIDY, M.B., Professor of Chemistry and Medical Jurisprudence at the London Hospital, 8vo, 16s.

VACHER.—A Primer of Chemistry, including Analysis. By ARTHUR VACHER. 18mo, 1s.

VALENTIN.—Chemical Tables for the Lecture-room and Laboratory. By WILLIAM G. VALENTIN, F.C.S. In Five large Sheets, 5s. 6d.

VALENTIN AND HODGKINSON.—A Course of Qualitative Chemical Analysis. By W. G. VALENTIN, F.C.S. Sixth Edition by W. R. HODGKINSON, Ph.D. (Wurzburg), Senior Demonstrator of Practical Chemistry in the Science Schools, South Kensington, and H. M. CHAPMAN, Assistant Demonstrator. With Engravings and Map of Spectra. 8vo, 8s. 6d.

The Tables for the Qualitative Analysis of Simple and Compound Substances, with Map of Spectra, printed separately on indestructible paper. 8vo, 2s. 6d.

CHEMISTRY—*continued.*

WATTS.—Physical and Inorganic Chemistry.
By HENRY WATTS, B.A., F.R.S. (being Vol. I. of the Thirteenth Edition of Fownes' Manual of Chemistry). With 150 Wood Engravings, and Coloured Plate of Spectra. Crown 8vo, 9s.

By the same Author.

Chemistry of Carbon-Compounds, or Organic Chemistry (being Vol. II. of the Thirteenth Edition of Fownes' Manual of Chemistry). Edited by WM. A. TILDEN, D.Sc., F.R.S. With Engravings. Crown 8vo, 10s.

CHILDREN, DISEASES OF.

DAY.—A Manual of the Diseases of Children.
By WILLIAM H. DAY, M.D., Physician to the Samaritan Hospital for Women and Children. Second Edition. Crown 8vo, 12s. 6d.

ELLIS.—A Practical Manual of the Diseases of Children. By EDWARD ELLIS, M.D., late Senior Physician to the Victoria Hospital for Sick Children. With a Formulary. Fourth Edition. Crown 8vo, 10s.

GOODHART.—The Student's Guide to Diseases of Children By JAMES F. GOODHART, M.D., F.R.C.P., Assistant Physician to Guy's Hospital; Physician to the Evelina Hospital for Sick Children. Second Edition. Fcap. 8vo. [*In the press.*

SMITH.—On the Wasting Diseases of Infants and Children. By EUSTACE SMITH, M.D., F.R.C.P., Physician to H.M. the King of the Belgians, and to the East London Hospital for Children. Fourth Edition. Post 8vo, 8s. 6d.

By the same Author.

A Practical Treatise on Disease in Children. 8vo, 22s.

STEINER.—Compendium of Children's Diseases; a Handbook for Practitioners and Students. By JOHANN STEINER, M.D. Translated by LAWSON TAIT, F.R.C.S., Surgeon to the Birmingham Hospital for Women, &c. 8vo, 12s. 6d.

DENTISTRY.

GORGAS. — Dental Medicine: a Manual of Dental Materia Medica and Therapeutics, for Practitioners and Students. By FERDINAND J. S. GORGAS, A.M., M.D., D.D.S., Professor of Dentistry in the University of Maryland; Editor of "Harris's Principles and Practice of Dentistry," &c. Royal 8vo, 14s.

HARRIS. — The Principles and Practice of Dentistry; including Anatomy, Physiology, Pathology, Therapeutics, Dental Surgery, and Mechanism. By CHAPIN A. HARRIS, M.D., D.D.S. Eleventh Edition, revised and edited by FERDINAND J. S. GORGAS A.M., M.D., D.D.S. With 750 Illustrations. 8vo, 31s. 6d.

SEWILL.—The Student's Guide to Dental Anatomy and Surgery. By HENRY E. SEWILL, M.R.C.S., L.D.S., late Dental Surgeon to the West London Hospital. Second Edition. With 78 Engravings. Fcap. 8vo, 5s. 6d.

STOCKEN.—Elements of Dental Materia Medica and Therapeutics, with Pharmacopœia. By JAMES STOCKEN, L.D.S.R.C.S., late Lecturer on Dental Materia Medica and Therapeutics and Dental Surgeon to the National Dental Hospital; assisted by THOMAS GADDES, L.D.S. Eng. and Edin. Third Edition. Fcap. 8vo, 7s. 6d.

TOMES (C. S.).—Manual of Dental Anatomy, Human and Comparative. By CHARLES S. TOMES, M.A., F.R.S. Second Edition. With 191 Engravings. Crown 8vo, 12s. 6d.

TOMES (J. and C. S.).—A Manual of Dental Surgery. By Sir JOHN TOMES, M.R.C.S., F.R.S., and CHARLES S. TOMES, M.A., M.R.C.S., F.R.S.; Lecturer on Anatomy and Physiology at the Dental Hospital of London. Third Edition. With many Engravings, Crown 8vo. [*Preparing.*

EAR, DISEASES OF.

BURNETT.—The Ear: its Anatomy, Physiology, and Diseases. A Practical Treatise for the Use of Medical Students and Practitioners. By CHARLES H. BURNETT, M.D., Aural Surgeon to the Presbyterian Hospital, Philadelphia. Second Edition. With 107 Engravings. 8vo, 18s.

DALBY.—On Diseases and Injuries of the Ear. By SIR WILLIAM B. DALBY, F.R.C.S., Aural Surgeon to, and Lecturer on Aural Surgery at, St. George's Hospital. Third Edition. With Engravings. Crown 8vo. 7s. 6d.

EAR, DISEASES OF—*continued.*

JONES.—A Practical Treatise on Aural Surgery. By H. MACNAUGHTON JONES, M.D., Professor of the Queen's University in Ireland, late Surgeon to the Cork Ophthalmic and Aural Hospital. Second Edition. With 63 Engravings. Crown 8vo, 8s. 6d.

By the same Author.

Atlas of the Diseases of the Membrana Tympani. In Coloured Plates, containing 59 Figures. With Explanatory Text. Crown 4to, 21s.

FORENSIC MEDICINE.

ABERCROMBIE. — The Student's Guide to Medical Jurisprudence. By JOHN ABERCROMBIE, M.D., F.R.C.P., Senior Assistant to, and Lecturer on Forensic Medicine at, Charing Cross Hospital. Fcap 8vo, 7s. 6d.

OGSTON.—Lectures on Medical Jurisprudence. By FRANCIS OGSTON, M.D., late Professor of Medical Jurisprudence and Medical Logic in the University of Aberdeen. Edited by FRANCIS OGSTON, Jun., M.D., late Lecturer on Practical Toxicology in the University of Aberdeen. With 12 Plates. 8vo, 18s.

TAYLOR.—The Principles and Practice of Medical Jurisprudence. By ALFRED S. TAYLOR, M.D., F.R.S. Third Edition, revised by THOMAS STEVENSON, M.D., F.R.C.P., Lecturer on Chemistry and Medical Jurisprudence at Guy's Hospital; Examiner in Chemistry at the Royal College of Physicians; Official Analyst to the Home Office. With 188 Engravings. 2 Vols. 8vo, 31s. 6d.

By the same Author.

A Manual of Medical Jurisprudence. Eleventh Edition, revised by THOMAS STEVENSON, M.D., F.R.C.P. With 56 Engravings. Crown 8vo, 14s.

ALSO,

On Poisons, in relation to Medical Jurisprudence and Medicine. Third Edition. With 104 Engravings. Crown 8vo, 16s.

TIDY AND WOODMAN.—A Handy-Book of Forensic Medicine and Toxicology. By C. MEYMOTT TIDY, M.B.; and W. BATHURST WOODMAN, M.D., F.R.C.P. With 8 Lithographic Plates and 116 Wood Engravings. 8vo, 31s. 6d.

HYGIENE.

PARKES.—A Manual of Practical Hygiene. By EDMUND A. PARKES, M.D., F.R.S. Sixth Edition by F. DE CHAUMONT, M.D., F.R.S., Professor of Military Hygiene in the Army Medical School. With 9 Plates and 103 Engravings. 8vo, 18s.

WILSON.—A Handbook of Hygiene and Sanitary Science. By GEORGE WILSON, M.A., M.D., F.R.S.E., Medical Officer of Health for Mid Warwickshire. Sixth Edition. With Engravings. Crown 8vo. [*In the press.*

MATERIA MEDICA AND THERAPEUTICS.

BINZ AND SPARKS.—The Elements of Therapeutics; a Clinical Guide to the Action of Medicines. By C. BINZ, M.D., Professor of Pharmacology in the University of Bonn. Translated and Edited with Additions, in conformity with the British and American Pharmacopœias, by EDWARD I. SPARKS, M.A., M.B., F.R.C.P. Lond. Crown 8vo, 8s. 6d.

LESCHER.—Recent Materia Medica. Notes on their Origin and Therapeutics. By F. HARWOOD LESCHER, F.C.S., Pereira Medallist. Second Edition. 8vo, 2s. 6d.

OWEN.—A Manual of Materia Medica; incorporating the Author's "Tables of Materia Medica." By ISAMBARD OWEN, M.D., F.R.C.P., Lecturer on Materia Medica and Therapeutics to St. George's Hospital. Second Edition. Crown 8vo, 6s. 6d.

ROYLE AND HARLEY.—A Manual of Materia Medica and Therapeutics. By J. FORBES ROYLE, M.D., F.R.S., and JOHN HARLEY, M.D., F.R.C.P., Physician to, and Joint Lecturer on Clinical Medicine at, St. Thomas's Hospital. Sixth Edition, including addition and alterations in the B.P. 1885. With 139 Engravings. Crown 8vo, 15s.

THOROWGOOD.—The Student's Guide to Materia Medica and Therapeutics. By JOHN C. THOROWGOOD, M.D., F.R.C.P., Lecturer on Materia Medica at the Middlesex Hospital. Second Edition. With Engravings. Fcap. 8vo, 7s.

WARING.—A Manual of Practical Therapeutics. By EDWARD J. WARING, C.I.E., M.D., F.R.C.P. Fourth Edition, revised by the Author and DUDLEY W. BUXTON, M.D., M.R.C.P. Crown 8vo, 14s.

MEDICINE.

BARCLAY.—A Manual of Medical Diagnosis. By A. WHYTE BARCLAY, M.D., F.R.C.P., late Physician to, and Lecturer on Medicine at, St. George's Hospital. Third Edition. Fcap. 8vo, 10s. 6d.

CHARTERIS.—The Student's Guide to the Practice of Medicine. By MATTHEW CHARTERIS, M.D., Professor of Therapeutics and Materia Medica, University of Glasgow; Physician to the Royal Infirmary. With Engravings on Copper and Wood. Fourth Edition. Fcap. 8vo, 9s.

FAGGE.—The Principles and Practice of Medicine. By the late C. HILTON FAGGE, M.D., F.R.C.P., Edited by P. H. PYE-SMITH, M.D., F.R.C.P., Physician to, and Lecturer on Medicine at, Guy's Hospital. 2 Vols. 8vo. Cloth, 36s.; half Persian, 42s.

FENWICK.—The Student's Guide to Medical Diagnosis. By SAMUEL FENWICK, M.D., F.R.C.P., Physician to the London Hospital. Sixth Edition. With 114 Engravings. Fcap. 8vo, 7s.

By the same Author.

The Student's Outlines of Medical Treatment. Second Edition. Fcap. 8vo, 7s.

FLINT.—Clinical Medicine: a Systematic Treatise on the Diagnosis and Treatment of Disease. By AUSTIN FLINT, M.D., Professor of the Principles and Practice of Medicine, &c., in Bellevue Hospital Medical College. 8vo, 20s.

WARNER.—The Student's Guide to Clinical Medicine and Case-Taking. By FRANCIS WARNER, M.D., F.R.C.P., Assistant-Physician to the London Hospital. Second Edition. Fcap. 8vo, 5s.

WEST.—How to Examine the Chest: being a Practical Guide for the Use of Students. By SAMUEL WEST, M.D., F.R.C.P., Physician to the City of London Hospital for Diseases of the Chest, &c. With 42 Engravings. Fcap. 8vo, 5s.

WHITTAKER.—Student's Primer on the Urine. By J. TRAVIS WHITTAKER, M.D., Clinical Demonstrator at the Royal Infirmary, Glasgow. With Illustrations, and 16 Plates etched on Copper. Post 8vo, 4s. 6d.

MIDWIFERY.

BARNES.—Lectures on Obstetric Operations, including the Treatment of Hæmorrhage, and forming a Guide to the Management of Difficult Labour. By ROBERT BARNES, M.D., F.R.C.P., Consulting Obstetric Physician to St. George's Hospital. Fourth (and cheaper) Edition. With 121 Engravings. 8vo, 12s. 6d.

BURTON.—Handbook of Midwifery for Midwives. By JOHN E. BURTON, M.R.C.S., L.R.C.P., Surgeon to the Liverpool Hospital for Women. Second Edition. With Engravings. Fcap 8vo, 6s.

GALABIN.—A Manual of Midwifery. By ALFRED LEWIS GALABIN, M.A., M.D., F.R.C.P., Obstetric Physician and Lecturer on Midwifery, &c., to Guy's Hospital, Examiner in Midwifery to the Conjoint Examining Board for England. With 227 Engravings. Crown 8vo, 15s.

RAMSBOTHAM.—The Principles and Practice of Obstetric Medicine and Surgery. By FRANCIS H. RAMSBOTHAM, M.D., formerly Obstetric Physician to the London Hospital. Fifth Edition. With 120 Plates, forming one thick handsome volume. 8vo, 22s.

REYNOLDS.—Notes on Midwifery: specially designed to assist the Student in preparing for Examination. By J. J. REYNOLDS, L.R.C.P., M.R.C.S. Second Edition. With 15 Engravings. Fcap. 8vo, 4s.

ROBERTS.—The Student's Guide to the Practice of Midwifery. By D. LLOYD ROBERTS, M.D., F.R.C.P., Lecturer on Clinical Midwifery and Diseases of Women at Owen's College, Physician to St. Mary's Hospital, Manchester. Third Edition. With 2 Coloured Plates and 127 Engravings. Fcap. 8vo, 7s. 6d.

SCHROEDER.—A Manual of Midwifery; including the Pathology of Pregnancy and the Puerperal State. By KARL SCHROEDER, M.D., Professor of Midwifery in the University of Erlangen. Translated by C. H. CARTER, M.D. With Engravings. 8vo, 12s. 6d.

SWAYNE.—Obstetric Aphorisms for the Use of Students commencing Midwifery Practice. By JOSEPH G. SWAYNE, M.D., Lecturer on Midwifery at the Bristol School of Medicine. Eighth Edition. With Engravings. Fcap. 8vo, 3s. 6d.

MICROSCOPY.

CARPENTER.—The Microscope and its Revelations. By WILLIAM B. CARPENTER, C.B., M.D., F.R.S. Sixth Edition. With about 600 Engravings. Crown 8vo, 16s.

LEE. — The Microtomist's Vade-Mecum; a Handbook of the Methods of Microscopic Anatomy. By ARTHUR BOLLES LEE. Crown 8vo, 8s. 6d.

MARSH. — Microscopical Section-Cutting: a Practical Guide to the Preparation and Mounting of Sections for the Microscope. By Dr. SYLVESTER MARSH. Second Edition. With 17 Engravings. Fcap. 8vo, 3s. 6d.

MARTIN.—A Manual of Microscopic Mounting. By J. H. MARTIN. Second Edition. With Plates and Wood Engravings. 8vo, 7s. 6d.

OPHTHALMOLOGY.

HARTRIDGE.—The Refraction of the Eye. By GUSTAVUS HARTRIDGE, F.R.C.S., Assistant Surgeon to the Royal Westminster Ophthalmic Hospital. Second Edition. With 94 Illustrations, Test Types, &c. Crown 8vo, 5s. 6d.

HIGGENS.—Hints on Ophthalmic Out-Patient Practice. By CHARLES HIGGENS, F.R.C.S., Ophthalmic Surgeon to, and Lecturer on Ophthalmology at, Guy's Hospital. Third Edition. Fcap. 8vo, 3s.

JONES.—A Manual of the Principles and Practice of Ophthalmic Medicine and Surgery. By T. WHARTON JONES, F.R.C.S., F.R.S., late Ophthalmic Surgeon and Professor of Ophthalmology to University College Hospital. Third Edition. With 9 Coloured Plates and 173 Engravings. Fcap. 8vo, 12s. 6d.

MACNAMARA.—A Manual of the Diseases of the Eye. By CHARLES MACNAMARA, F.R.C.S., Surgeon to, and Lecturer on Surgery at, the Westminster Hospital. Fourth Edition. With 4 Coloured Plates and 66 Engravings. Crown 8vo, 10s. 6d.

NETTLESHIP.—The Student's Guide to Diseases of the Eye. By EDWARD NETTLESHIP, F.R.C.S., Ophthalmic Surgeon to, and Lecturer on Ophthalmic Surgery at, St. Thomas's Hospital. Third Edition. With 157 Engravings, and a Set of Coloured Papers illustrating Colour-blindness. Fcap. 8vo, 7s. 6d.

OPHTHALMOLOGY—*continued.*

TOSSWILL.—Diseases and Injuries of the Eye and Eyelids. By Louis H. Tosswill, B.A., M.B. Cantab., M.R.C.S., Surgeon to the West of England Eye Infirmary, Exeter. Fcap. 8vo, 2s. 6d.

WOLFE.—On Diseases and Injuries of the Eye: a Course of Systematic and Clinical Lectures to Students and Medical Practitioners. By J. R. Wolfe, M.D., F.R.C.S.E., Senior Surgeon to the Glasgow Ophthalmic Institution, Lecturer on Ophthalmic Medicine and Surgery in Anderson's College. With 10 Coloured Plates, and 120 Wood Engravings, 8vo, 21s.

PATHOLOGY.

JONES AND SIEVEKING.—A Manual of Pathological Anatomy. By C. Handfield Jones, M.B., F.R.S., and Edward H. Sieveking M.D., F.R.C.P. Second Edition. Edited, with considerable enlargement, by J. F. Payne, M.B., Assistant-Physician and Lecturer on General Pathology at St. Thomas's Hospital. With 195 Engravings. Crown 8vo, 16s.

LANCEREAUX.—Atlas of Pathological Anatomy. By Dr. Lancereaux. Translated by W. S. Greenfield, M.D., Professor of Pathology in the University of Edinburgh. With 70 Coloured Plates. Imperial 8vo, £5 5s.

SUTTON. — An Introduction to General Pathology. By John Bland Sutton, F.R.C.S., Sir E. Wilson Lecturer on Pathology, R.C.S.; Assistant Surgeon to, and Lecturer on Anatomy at, Middlesex Hospital. With 149 Engravings. 8vo, 14s.

VIRCHOW. — Post-Mortem Examinations: a Description and Explanation of the Method of Performing them, with especial reference to Medico-Legal Practice. By Professor Rudolph Virchow, Berlin Charité Hospital. Translated by Dr. T. B. Smith. Second Edition, with 4 Plates. Fcap. 8vo, 3s. 6d.

PSYCHOLOGY.

BUCKNILL AND TUKE.—A Manual of Psychological Medicine: containing the Lunacy Laws, Nosology, Ætiology, Statistics, Description, Diagnosis, Pathology, and Treatment of Insanity, with an Appendix of Cases. By John C. Bucknill, M.D., F.R.S., and D. Hack Tuke, M.D., F.R.C.P. Fourth Edition with 12 Plates (30 Figures). 8vo, 25s.

PSYCHOLOGY—*continued.*

CLOUSTON. — **Clinical Lectures on Mental** Diseases. By THOMAS S. CLOUSTON, M.D., and F.R.C.P. Edin.; Lecturer on Mental Diseases in the University of Edinburgh. With 8 Plates (6 Coloured). Crown 8vo, 12s. 6d.

PHYSICS.

DRAPER.—**A Text Book of Medical Physics,** for the use of Students and Practitioners of Medicine By JOHN C. DRAPER, M.D., LL.D., Professor of Chemistry and Physics in the University of New York. With 377 Engravings. 8vo, 18s.

PHYSIOLOGY.

CARPENTER.—**Principles of Human Physiology.** By WILLIAM B. CARPENTER, C.B., M.D., F.R.S. Ninth Edition. Edited by Henry Power, M.B., F.R.C.S. With 3 Steel Plates and 377 Wood Engravings. 8vo, 31s. 6d.

DALTON.—**A Treatise on Human Physiology:** designed for the use of Students and Practitioners of Medicine. By JOHN C. DALTON, M.D., Professor of Physiology and Hygiene in the College of Physicians and Surgeons, New York. Seventh Edition. With 252 Engravings. Royal 8vo, 20s.

FREY.—**The Histology and Histo-Chemistry of** Man. A Treatise on the Elements of Composition and Structure of the Human Body. By HEINRICH FREY, Professor of Medicine in Zurich. Translated by ARTHUR E. BARKER, Assistant-Surgeon to the University College Hospital. With 608 Engravings. 8vo, 21s.

PYE-SMITH.—**Syllabus of a Course of Lectures** on Physiology. By PHILIP H. PYE-SMITH, B.A., M.D., F.R.C.P., Physician to Guy's Hospital. With Diagrams, and an Appendix of Notes and Tables. Crown 8vo, 5s.

SANDERSON.—**Handbook for the Physiological** Laboratory: containing an Exposition of the fundamental facts of the Science, with explicit Directions for their demonstration. By J. BURDON SANDERSON, M.D., F.R.S.; E. KLEIN, M.D., F.R.S.; MICHAEL FOSTER, M.D., F.R.S., and T. LAUDER BRUNTON, M.D., F.R.S. 2 Vols., with 123 Plates. 8vo, 24s.

YEO.—**A Manual of Physiology for the Use of** Junior Students of Medicine. By GERALD F. YEO, M.D., F.R.C.S., Professor of Physiology in King's College, London. With 301 Engravings. Crown 8vo, 14s.

SURGERY.

BELLAMY.—The Student's Guide to Surgical Anatomy; an Introduction to Operative Surgery. By EDWARD BELLAMY, F.R.C.S., and Member of the Board of Examiners; Surgeon to, and Lecturer on Anatomy at, Charing Cross Hospital. Third Edition. With 80 Engravings. Fcap. 8vo, 7s. 6d.

BRYANT.—A Manual for the Practice of Surgery. By THOMAS BRYANT, F.R.C.S., Surgeon to, and Lecturer on Surgery at, Guy's Hospital. Fourth Edition. With 750 Illustrations (many being coloured), and including 6 Chromo-Lithographic Plates. 2 Vols. Crown 8vo, 32s.

CLARK AND WAGSTAFFE. — Outlines of Surgery and Surgical Pathology. By F. LE GROS CLARK, F.R.C.S., F.R.S., Consulting Surgeon to St. Thomas's Hospital. Second Edition. Revised and expanded by the Author, assisted by W. W. WAGSTAFFE, F.R.C.S., Assistant Surgeon to St. Thomas's Hospital. 8vo, 10s. 6d.

DRUITT.—The Surgeon's Vade-Mecum; a Manual of Modern Surgery. By ROBERT DRUITT, F.R.C.S. Twelfth Edition. With many Engravings. Fcap. 8vo. [*In the press.*

FERGUSSON.—A System of Practical Surgery. By Sir WILLIAM FERGUSSON, Bart., F.R.C.S., F.R.S., late Surgeon and Professor of Clinical Surgery to King's College Hospital. With 463 Engravings. Fifth Edition. 8vo, 21s.

HEATH.—A Manual of Minor Surgery and Bandaging, for the use of House-Surgeons, Dressers, and Junior Practitioners. By CHRISTOPHER HEATH, F.R.C.S., Holme Professor of Clinical Surgery in University College and Surgeon to the Hospital. Seventh Edition. With 129 Engravings. Fcap. 8vo, 6s.

By the same Author.

A Course of Operative Surgery: with Twenty Plates (containing many figures) drawn from Nature by M. LÉVEILLÉ, and Coloured. Second Edition. Large 8vo, 30s.

ALSO,

The Student's Guide to Surgical Diagnosis. Second Edition. Fcap. 8vo, 6s. 6d.

SURGERY—*continued.*

SOUTHAM.—Regional Surgery: including Surgical Diagnosis. A Manual for the use of Students. By FREDERICK A. SOUTHAM, M.A., M.B. Oxon, F.R.C.S., Assistant-Surgeon to the Royal Infirmary, and Assistant-Lecturer on Surgery in the Owen's College School of Medicine, Manchester.

Part I. The Head and Neck. Crown 8vo, 6s. 6d.
,, II. The Upper Extremity and Thorax. Crown 8vo, 7s. 6d.
,, III. The Abdomen and Lower Extremity. Crown 8vo, 7s.

TERMINOLOGY.

DUNGLISON.—Medical Lexicon: a Dictionary of Medical Science, containing a concise Explanation of its various Subjects and Terms, with Accentuation, Etymology, Synonyms, &c. By ROBERT DUNGLISON, M.D. New Edition, thoroughly revised by RICHARD J. DUNGLISON, M.D. Royal 8vo, 28s.

MAYNE.—A Medical Vocabulary: being an Explanation of all Terms and Phrases used in the various Departments of Medical Science and Practice, giving their Derivation, Meaning, Application, and Pronunciation. By ROBERT G. MAYNE, M.D., LL.D., and JOHN MAYNE, M.D., L.R.C.S.E. Fifth Edition. Crown 8vo, 10s. 6d.

WOMEN, DISEASES OF.

BARNES.—A Clinical History of the Medical and Surgical Diseases of Women. By ROBERT BARNES, M.D., F.R.C.P., Obstetric Physician to, and Lecturer on Diseases of Women, &c., at, St. George's Hospital. Second Edition. With 181 Engravings. 8vo, 28s.

COURTY.—Practical Treatise on Diseases of the Uterus, Ovaries, and Fallopian Tubes. By Professor COURTY, Montpellier. Translated from the Third Edition by his Pupil, AGNES M'LAREN, M.D., M.K.Q.C.P. With Preface by Dr. MATTHEWS DUNCAN. With 424 Engravings. 8vo, 24s.

DUNCAN.—Clinical Lectures on the Diseases of Women. By J. MATTHEWS DUNCAN, M.D., F.R.C.P., F.R.S.E., Obstetric Physician to St. Bartholomew's Hospital. Third Edition. 8vo. [*In the press.*

EMMET.—The Principles and Practice of Gynæcology. By THOMAS ADDIS EMMET, M.D., Surgeon to the Woman's Hospital of the State of New York. Third Edition. With 150 Engravings. Royal 8vo, 24s.

WOMEN, DISEASES OF—*continued.*

GALABIN.—The Student's Guide to the Diseases of Women. By ALFRED L. GALABIN, M.D., F.R.C.P., Obstetric Physician to, and Lecturer on Obstetric Medicine at, Guy's Hospital. Third Edition. With 78 Engravings. Fcap. 8vo, 7s. 6d.

REYNOLDS.—Notes on Diseases of Women. Specially designed to assist the Student in preparing for Examination. By J. J. REYNOLDS, L.R.C.P., M.R.C.S. Third Edition. Fcap. 8vo, 2s. 6d.

SAVAGE.—The Surgery of the Female Pelvic Organs. By HENRY SAVAGE, M.D., Lond., F.R.C.S., one of the Consulting Medical Officers of the Samaritan Hospital for Women. Fifth Edition, with 17 Lithographic Plates (15 Coloured), and 52 Woodcuts. Royal 4to, 35s.

WEST AND DUNCAN.—Lectures on the Diseases of Women. By CHARLES WEST, M.D., F.R.C.P. Fourth Edition. Revised and in part re-written by the Author, with numerous additions by J. MATTHEWS DUNCAN, M.D., F.R.C.P., F.R.S.E., Obstetric Physician to St. Bartholomew's Hospital. 8vo, 16s.

ZOOLOGY.

CHAUVEAU AND FLEMING.—The Comparative Anatomy of the Domesticated Animals. By A. CHAUVEAU, Professor at the Lyons Veterinary School; and GEORGE FLEMING, Veterinary Surgeon, Royal Engineers. With 450 Engravings. 8vo, 31s. 6d.

HUXLEY.—Manual of the Anatomy of Invertebrated Animals. By THOMAS H. HUXLEY, LL.D., F.R.S. With 156 Engravings. Post 8vo, 16s.

By the same Author.

Manual of the Anatomy of Vertebrated Animals. With 110 Engravings. Post 8vo, 12s.

WILSON.—The Student's Guide to Zoology: a Manual of the Principles of Zoological Science. By ANDREW WILSON, Lecturer on Natural History, Edinburgh. With Engravings. Fcap. 8vo, 6s. 6d.